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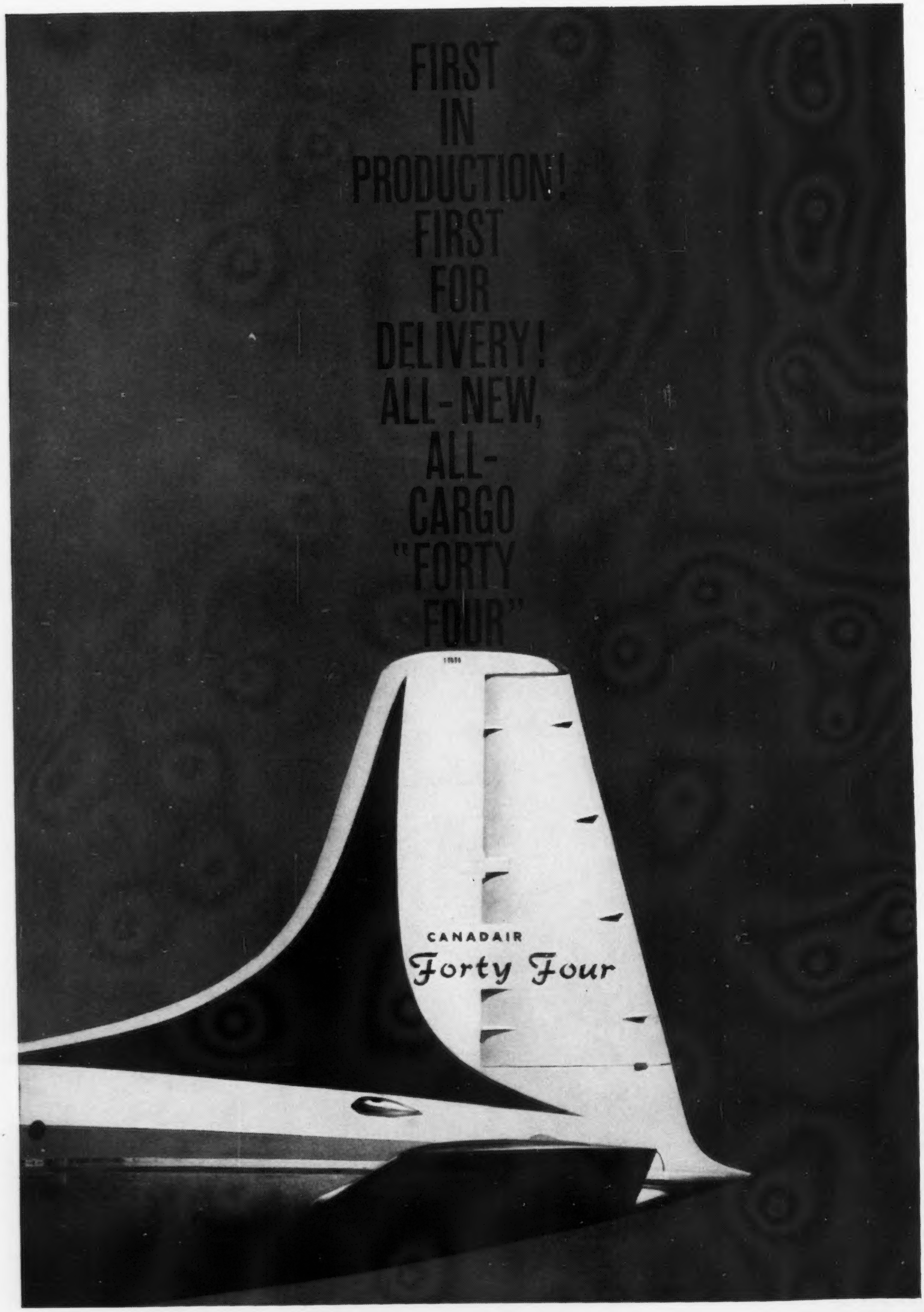
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THERE ARE NO IFS, ANDS OR BUTS ABOUT THE CANADAIR FORTY FOUR. It is a "here and now" swing-tail cargoplane, at least 18 months ahead of comparable aircraft still in the "talking stage." The turbo-prop "Forty Four" is in full production for the Royal Canadian Air Force and two leading American airlines. It has already been through the development stage and its Rolls-Royce Tyne engines have been thoroughly tested and proved. With the "Forty Four" in your fleet, you can be 18 months ahead of competition and in a most favorable earning position.

First photographs of the Canadair Forty Four, taken September 30, 1959 in Montreal. The "Forty Four" is now on the line for the Royal Canadian Air Force, the Flying Tiger Line, Seaboard and Western Airlines Inc.

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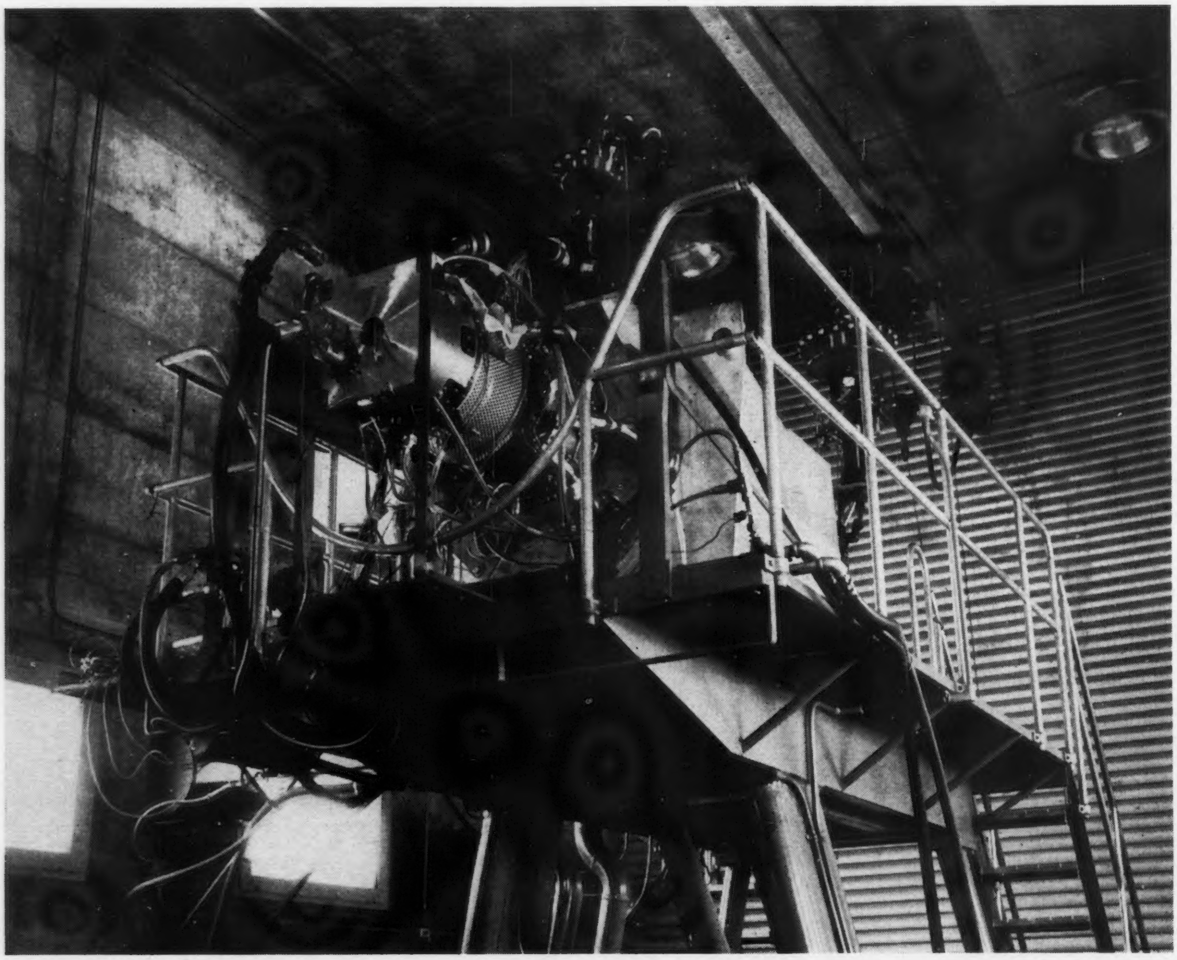
CANADIAN PRATT & WHITNEY PT6



The PT6 turboprop/turboshaft engine undergoing test in the new Canadian Pratt & Whitney test cell

EDITORIAL

SERVICE

THE value of a good service department becomes very evident to most of us when the oil burner ceases to work at about 2.00 am on a cold December day or when the washing machine proceeds to fill the basement rather than the tub with hot water. It is even more evident when, after some frenzied work and bad language, one discovers that one's mechanical ability has deteriorated suddenly and that there is, after all, no substitute for someone with access to spare parts and with some knowledge of how the thing was intended to work.

Aircraft are more complicated by several degrees than appliances (although the appliances are rapidly catching up), but the same basic rule applies to both. This is that aircraft – or appliances – can be successfully maintained only by people who are properly trained, who have complete technical information, who have access to the necessary spares and who are equipped with the tools required to do the work.

In the realms both of appliances and of aircraft, this is too often forgotten. Under the spell of an appliance salesman or the Director of Aircraft Sales, and in a rosy glow either naturally or artificially stimulated, the would-be operator forgets that the shiny gadget he is about to buy is a mechanical gadget which, without maintenance, is subject to failure – usually at the most embarrassing possible moment. The result is that technical and spares support, if it is thought of at all, is usually one of the "details to be negotiated later", and the support program ends up at about a quarter of what it should be, after most of the extra funds have been set aside for gingerbread.

Maintenance of a large contemporary aircraft involves a great deal of effort, particularly in the preparation of basic data required to support it. For example, an automobile shop maintenance manual might run to about 300 pages, and the corresponding parts manual to 250 including illustrations. The DC-8 maintenance manual, on the other hand, is divided into sections and totals approximately 2,100 pages including some 700 illustrations. The parts manual has approximately 690 pages, of which one-third are illustrations. When these are added to the pilot's operating instructions and other manuals specified by the Air Transport Association, the preparation of the entire series, exclusive of printing, represents the combined effort of fifty men for over a year. As a further example, general aircraft knowledge can no longer be considered as a complete qualification for aircraft maintenance and any technical support program must include the provision of a technical training school in which full-time courses on the various aircraft systems can be given. These courses may range in length from two to six weeks and may extend to four months if complete familiarity with all the systems is required. All this reflects nothing more than the complexity of present-day aircraft and the extra effort to provide technical support for an effective maintenance program is amply repaid by increased aircraft reliability and utilization.

It has been estimated that a complete technical support program including publications, technical liaison and initial training represents approximately 2% of the cost of a contemporary four-engined transport aircraft and that the necessary spares, if ordered in time, represent a further 10%. Considering the utilization which must be achieved to support the investment which one of these aircraft represents, this additional expenditure, apart from being essential, would appear to be pretty good value for the money.

E. C. V. NORSWORTHY
Manager, Service Department
Canadair Limited

CANADIAN PRATT AND WHITNEY PT6

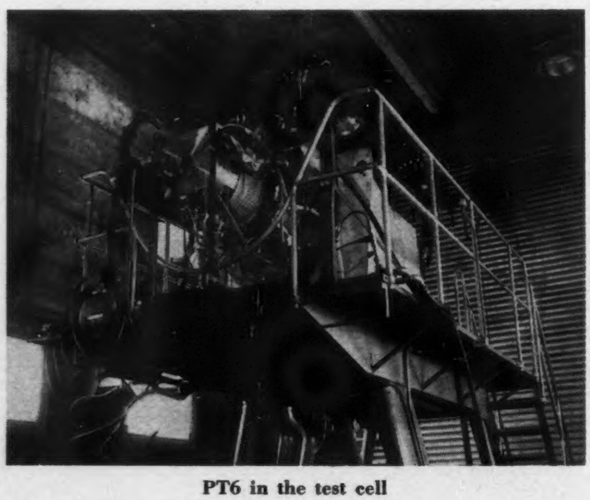
CANADIAN Pratt and Whitney Aircraft Company Limited have announced the development of a small lightweight free turbine engine designed for low cost use in light planes and helicopters.

The engine, designated the PT6, has two versions, the turboprop and the turboshaft.

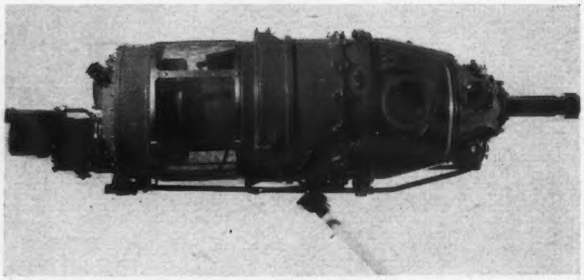
The turboprop version, weighs 250 pounds and develops 500 equivalent horsepower. This version, which the company engineers say has a generous growth potential, offers a guaranteed maximum specific fuel consumption of 0.69 pounds per equivalent shaft horsepower per hour. In the turboprop form, this engine will be used in light planes.

The turboshaft version weighs only 225 pounds, 25 pounds less than the turboprop version. This engine produces 500 horsepower at takeoff conditions. This version will be used in helicopters.

The United Aircraft Corporation's Canadian subsidiary shared in the initial design work of the JT12, a 436 pound turbojet engine with 3,000 pounds of thrust, which was introduced last year by Pratt and Whitney Aircraft of East Hartford, Connecticut. With that successful engine as a background, the Canadian company undertook the design and development of the still smaller PT6.



PT6 in the test cell



PT6 turboprop/turboshaft engine

The PT6 was designed for light and medium single and multi-engine planes and helicopters, as well as aircraft with vertical takeoff and landing capabilities. Thus the design permits continuous engine operation with the thrust axis inclined from 45° nose down to 110° nose up.

Some of the listed advantages are: easy maintenance, with a minimum of servicing between overhaul periods of 1,000 hours; an integral oil tank providing a self-contained lubricating system for the engine and propeller, eliminating airframe connections and a lower overall engine noise level.

Designers reversed the conventional engine layout in the PT6, avoiding use of concentric shafting. Most installations will utilize a scoop-type cowling inlet. The air enters the engine near the rear of the nacelle, similar to the carburetor scoop position on a piston-engine aircraft, and is compressed by a single compressor assembly connected with the first turbine. The second, or free turbine, is spun by the gas flow of the first turbine and is directly linked, through reduction gearing in the nose section, to the propeller shaft. Exhaust gases are discharged through twin ports on each side of the nacelle aft of the nose section.

A single stage of gearing provides 6,000 output shaft rpm for the turboshaft version. A second stage of gearing in the turboprop version provides 2,400 propeller rpm.

Studies on the PT6 began in October, 1958, but detailed design did not begin until early this year. Development testing is now underway and prototype flight engines will be available in 1961.

FLIGHT TRIALS OF THE SILVER DART†

by W/C P. A. Hartman*

Royal Canadian Air Force

INTRODUCTION

THE story of the initial building of the replica Silver Dart by LAC Lionel McCaffrey, assisted by his associated tradesmen at Trenton, Ontario, and the final flight of the aircraft at Baddeck, Nova Scotia, on February 23, 1959, is well known and needs no repetition. That final flight was the culmination of a programme of work on the aircraft which began in the fall of 1958 with the decision that the replica was to be made airworthy and included, in addition to an aerodynamic and structural analysis and the incorporation of certain essential structural modifications, a series of ground handling and flight trials. The interest evinced by many members of the aeronautical community in the flight trials of the replica Silver Dart, the Silver Dart Mk 2 as the aircraft was officially designated, has prompted the writing of the following brief summary of the trials that were conducted.

PREPARATION OF THE AIRCRAFT

A project team was established to implement the decision to prepare the aircraft for flight. The team consisted of F/L W. K. Bell, aerodynamics and structures engineer; F/O C. V. Walker, project maintenance engineer; the author, as test pilot; and a group of aircraft technicians consisting of LAC L. McCaffrey and LAC M. Trimm supervised by Sgt. H. C. Pangborne. The facilities of the RCAF's No. 6 Repair Depot at Trenton were also made available. The replica was taken to the RCAF Station at Mountainview, Ontario, where the work of preparing the aircraft for flight was begun.

The RCAF directive which initiated the programme stated the task for which the aircraft was being made airworthy as "to simulate as near as possible the first flight of the original Silver Dart". The most authoritative data concerning the first flight of the original aircraft in Canada was contained in the station records compiled by Dr. Alexander Graham Bell. These records showed that the first flight was made over a straight-line distance of approximately a half mile, during which a maximum height of about 20 ft had been attained. Obviously, duplication of this flight would be a simple matter as long as the aircraft was capable of flying and the flight was restricted to conditions of light winds and no gusts.

There were, however, other factors which were of importance in establishing the aircraft's flight envelope. No doubt existed regarding the ability of the aircraft to fly; the original aircraft had demonstrated that ability on at least 300 occasions according to the Honourable J. A. D. McCurdy, pilot of the original Silver Dart. However, an allowance had to be made for minor inadvertent manoeuvres, gusts, roll correction, yaw correction, landing loads, etc. Thus, the following design conditions were established for the replica aircraft:

(a) Takeoff speed would be approximately 30 mph.

(b) Cruising speed would be approximately 40 mph. (Terminal velocity dive speed was calculated to be about 90 mph but the airframe structure was incapable of sustaining such a speed.)

(c) Landing sink speeds of 6 fps were set for purposes of design (this was an arbitrarily established value).

(d) A structural limit load factor of 1.5g was set, with an ultimate load factor of 2g. These limitations were considered adequate for light gusts and inadvertent manoeuvres.

(e) Altitude limitation was set by policy at 20 ft.

(f) 10° yaw was allowed for in studies.

(g) Roll control requirements were considered to be just sufficient to correct for wing dropping; however, the values obtained were purely empirical.

(h) Crash loads of 4.5g restraint were considered for the pilot, with 9g for the motor and certain parts of the centresection. (It was desirable, with the aft mounting of the engine, that the pilot should break free from the seat before the engine left its mounting.)

As the replica airframe, shown in Figure 1, was more closely examined, it became apparent that several changes would have to be made. The aircraft had been built to AEA (Aerial Experiment Association) drawings dated October 20, 1908. These drawings were compiled for patent purposes and did not present many of the essential constructional details of the original aircraft. Addition-

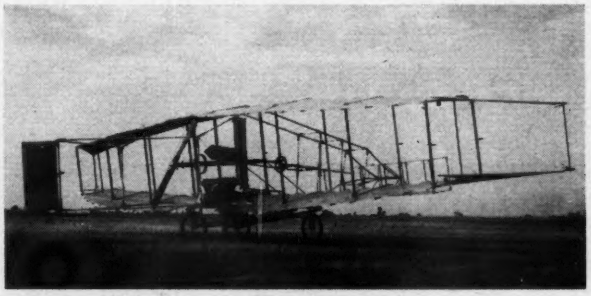


Figure 1
The replica Silver Dart at Mountainview aerodrome

†Based on a paper presented to the Ottawa Branch of the C.A.I. on the 13th May, 1959.

*Directorate of Maritime, Transport, Tactical and Training Requirements.

ally, the drawings did not include changes made to the original aircraft as a result of the trial flights made at Hammondsport, New York, prior to its first flight at Baddeck. Thus, the replica airframe was found, on structural analysis, to be deficient in several respects. The aircraft was stripped to the basic structure and rebuilt to the above noted design conditions.

The reconstructed replica was authentic in all major respects with the following exceptions:

(a) Correct gauge aircraft cable was used throughout for the flying, landing and drag wires, and small diameter chrome-molybdenum tubing was added to reinforce certain critical areas.

(b) Small diameter motorcycle wheels and tires were substituted for the sulky or bicycle wheels and tires used on the original aircraft.

(c) A 65 hp Continental air-cooled engine was installed in lieu of the 50 hp Curtiss V-8 engine employed in the original aircraft (the latter engine was obviously not available).

(d) The propeller was attached directly to the crankshaft of the engine rather than being affixed to a separate belt- or chain-driven shaft mounted above the engine, as it was in the original.

(e) The wing angle of incidence was reduced from the 13° shown on the AEA drawings to 11°. This change was effected to preclude the aircraft becoming airborne with the wing critically close to a stalled condition. The change was made by shortening the nose wheel leg prior to the first RCAF flight. (A similar change had been made on the original Silver Dart prior to its flight at Baddeck, but the change wasn't apparent to the engineers of the group until the records and drawings in the Bell Museum were studied just prior to the flight of the replica on February 23, 1959.)

The wings, the majority of the control system runs and all control surfaces of the replica Silver Dart were reproduced precisely as shown in the available drawings of the original aircraft. The control surfaces were, however, strengthened at the hinge points and control line attachment points.

DIMENSIONS AND DESIGN CHARACTERISTICS

The major dimensions and design characteristics of the Silver Dart Mk 2 aircraft were as follows:

Wing span	49 ft 2 in
Length	32 ft 10 in
Anhedral of upper mainplane	3°
Dihedral of lower mainplane	3°
Wing area (less aileron area)	395.5 sq ft
Aileron area	24.5 sq ft
Elevator area	56 sq ft
Rudder area	8 sq ft
AUW (minus pilot)	940 lb
Wing loading	2.78 lb/sq ft
Maximum camber	4″ at ¼c
CG position (pilot and 5 gals fuel)	6½″ fwd of ¼ chord point of MAC
Effective aspect ratio	Approx. 14.5
Mean aerodynamic chord	68.2 in

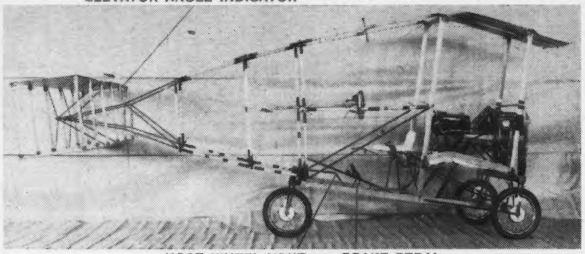


Figure 2
Port side view (less wings and rudder assembly)

Control surface travel:

Rudder	20° left and right
Elevator	+15° and −10°
Ailerons	±15°

(All control surfaces were plane sections.)

CONTROL SYSTEMS AND INSTRUMENTATION

The aircraft was a pusher biplane of canard configuration having an all-moving biplane elevator which functioned as both a horizontal stabilizer and a longitudinal control. The elevator was actuated by a push-pull motion of the control wheel; the system is clearly visible in Figure 2. The pilot's control wheel was attached by cables to a yoke which extended aft from the nose wheel, and the rudder cables were attached to this yoke. Thus, movement of the control wheel provided rudder control and nose wheel steering. The rudder, which was mounted aft in the normal position, was not attached to any fixed vertical fin. Indeed, the aircraft had no fixed vertical stabilizing surface and the rudder provided both directional stability and control.

The ailerons were triangular sections attached to the tips of the upper and lower mainplanes. They were actuated by a control yoke which fitted snugly about the pilot's shoulders. The aileron control system was rigged in such a manner that lateral control was obtained by the pilot leaning in the desired direction of lateral manoeuvre, i.e. the pilot leaned away from a down-going wing, thus imparting a control motion which raised the wing by increasing the aileron angle.

The ailerons were rigged with 8° of "up" float because calculations showed that the angle of attack of the wing would be approximately 8° with the aircraft in cruising flight at 38-40 mph indicated air speed.

The replica differed from the original Silver Dart in one important aspect; advantage was taken of the friction brakes which were an integral part of the motorcycle wheels and the aircraft was provided with a pedal actuated brake system. Although this was a distinct departure from the original aircraft, the brakes proved to be most useful during flight tests from the runways at Mountainview. The nose wheel yoke and brake pedal are also shown in Figure 2.

The following instrumentation was provided:

(a) A vane type airspeed indicator, calibrated by the National Research Council, was mounted on the end of a boom which was affixed to, and extended about 3 ft forward of, the lower port mainplane.

(b) A magneto switch, tachometer and engine oil pressure gauge were mounted on a panel located to the left of the control wheel, as shown in Figure 3.

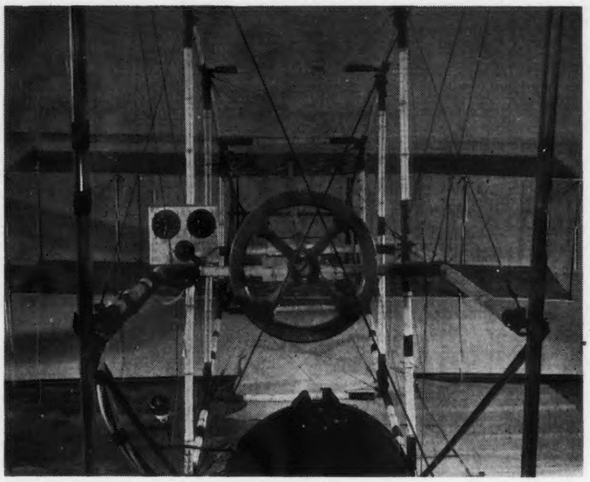


Figure 3
Pilot's forward view

(c) An elevator angle indicator was mounted vertically on the elevator support structure and adjacent to the trailing edge of the upper plane of the elevator. This consisted of a rod calibrated, with ½″ wide white stripes, in 5° increments of elevator movement. A black paint stripe was also placed on the trailing edge of the upper plane of the elevator. (The pilot selected the desired elevator angle for takeoff by visually positioning the trailing edge of the elevator in line with the appropriate stripe on the rod.) This device is shown in Figure 4.

(d) A yaw indicator, consisting of a small paper cone suspended by a piece of string from one of the bamboo cross members of the elevator supporting structure, was installed. Also visible in Figure 4.

GROUND RUNS

The method of construction adopted by the Aerial Experiment Association was unique in that it enabled us to conduct the essential ground tests coincident with the progressive assembly of the aircraft. The first tests consisted of a series of taxi runs made with the main centresection of the aircraft minus elevator, wings and rudder. These test runs enabled us to check the nose wheel steering and the accuracy of readings obtained on the airspeed indicator and to get a general feel for the engine operating characteristics. The engine installation is shown in Figure 5 and the main centresection is shown during a taxi run in Figure 6.

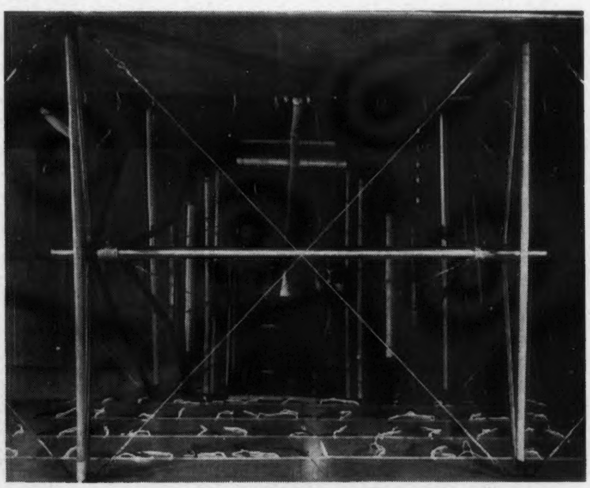


Figure 4
View aft of centresection from in front of elevator assembly

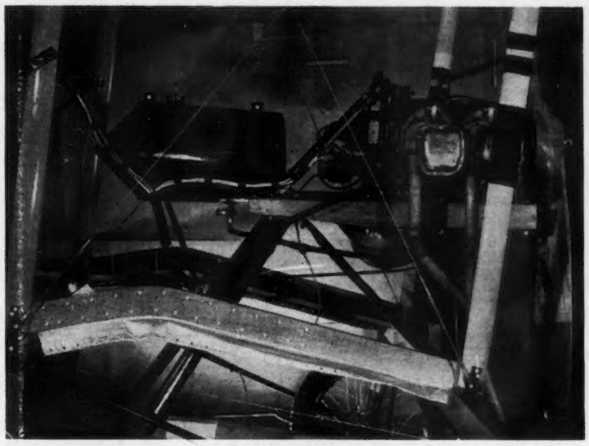


Figure 5
Close-up of engine installation

The nose wheel steering was found to be overly sensitive. This condition was rectified by halving the ratio between the control wheel and the nose wheel yoke. It was accomplished by adding an additional pulley to both sides of the yoke. This change resulted in excellent ground handling characteristics.

The response of the engine to throttle operation was excellent. As might be imagined, the bare centresection accelerated quite rapidly and on several runs at 50 mph it initially out-distanced the pacing automobile by a considerable margin — approximately 100 ft on some occasions. There was a noticeable lack of vibration from the engine during even full power operation.

The airspeed indicator showed accurate readings throughout the speed range from 15 to 50 mph. (The speedometer of the pacing automobile had been previously calibrated by timed runs over a measured mile.) An allowance was made for the wind speeds prevailing during the taxi runs.

The brakes functioned satisfactorily throughout the trials.

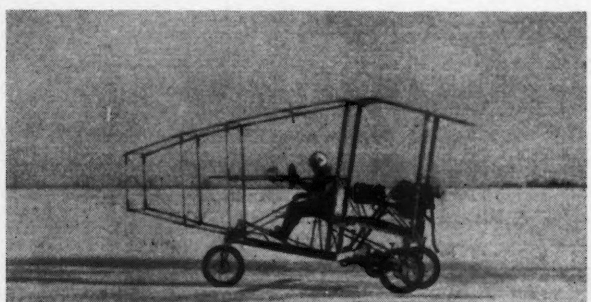


Figure 6
Centresection undergoing taxi trials

The elevator was added to the centresection, and a series of trial runs were made to obtain a qualitative indication of its effectiveness. The elevator was liberally tufted with wool (shown in Figures 3 and 4) to provide a clear indication to the pilot of the angle and speeds at which the section would become stalled. The centresection was also ballasted to simulate the all-up weight and centre of gravity of the complete aircraft.

It was observed during these runs that with the elevator set at approximately 5° nose up at speeds of 30 mph the load on the nose wheel was considerably reduced. The nose wheel was, in fact, almost clear of the ground.

Skids, consisting of two 6 ft sections of 2" × 4" lumber, were then added to the rear of the centresection to prevent it rearing too far into the air, and further runs were made at increased elevator angles. This proved to be a wise precaution because on a subsequent run at 30 mph with the elevator set at approximately 8° nose up, the vehicle reared up sufficiently to drag the ends of the skids along the ground. Further runs were discontinued primarily because all directional control of the centresection was lost the instant the nose wheel left the ground and, additionally, because we had obtained sufficient indication of the effectiveness of the elevator as a control surface.

The wings and rudder were added to the aircraft and final preparations were made for the test flights.

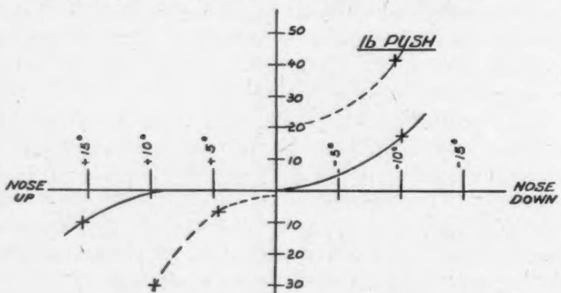


Figure 7
Estimated curve of elevator angle vs control force — 40 mph

TEST FLIGHTS

It was considered essential that we regard the aircraft as an untried prototype insofar as flying it was concerned, because the kinematics of the control system were a distinct departure from present day practice. This is clearly illustrated by the graph, Figure 7, of estimated control forces and their variation with elevator angle.

The curves shown in Figure 7 were provided by F/L Bell, and were established by theoretical analysis and empirical data on wing pitching moments obtained from tests conducted on the rig shown in Figure 8. The dashed curves apply to the steady state, constant speed condition, and the solid line is the estimated resultant after allowing for the dynamics of the aircraft's response to control displacement. The complete implications of the solid curve are apparent when it is related to the estimated static longitudinal stability curve of elevator angle versus speed for level flight, shown in Figure 9.

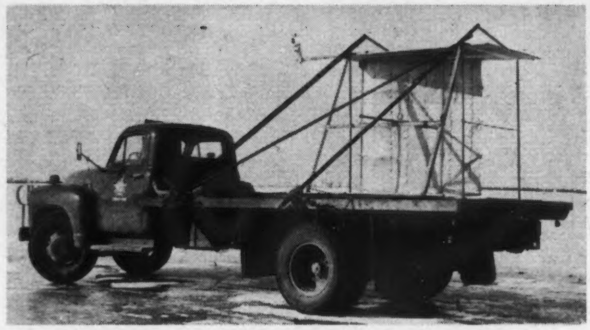


Figure 8
Mobile airfoil testing apparatus

It was apparent that if our calculations were correct the aircraft would exhibit positive static longitudinal stability, but would be operating within the zero control force/elevator angle range. This was not, however, entirely correct because there was approximately 2-3 lb friction within the elevator control system, although all points of contact between the control rod and the structure had been liberally greased. (It should be noted that the elevator hinge was located at 22.9% of the chord line, providing a degree of aerodynamic balance.)

It was estimated that the aircraft would become airborne at approximately 30 mph. Therefore, bearing in mind the implications of the curves in Figures 7 and 9, the first flight was to be accomplished by adopting the following technique:

(a) the brakes were to be set and the throttle opened to 1,950 rpm (a setting which provided approximately 28-30 effective thrust horsepower at 30 mph),
(b) the elevator was to be set and held at the 5° nose up mark on the indicator,
(c) the brakes were to be released and the aircraft allowed to fly off from a three-point attitude.

The first flights were made from the runway at Mountainview on January 29, 1959, under conditions of zero wind. The technique outlined in the preceding paragraph was adopted for the first flight and the aircraft became airborne precisely in accord with our estimates. It displayed no pitching tendency following takeoff. The flight was short, being approximately 80 ft in length, during which a maximum altitude of 4 ft was attained.

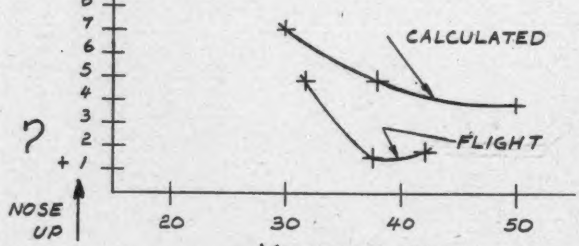


Figure 9
Estimated curve of elevator angle vs speed for level flights

Three more flights were made that day. They were all straight-line flights along the runway. The flights are listed below:

No.	Duration of Flight	Distance Flown	Height	Wind
1	2 sec	80 ft	4 ft	nil
2	8 sec	350 ft	15 ft	nil
3	15 sec	700 ft	30 ft	nil
4	34 sec	1650 ft	30 ft	nil

The fourth flight made was the most interesting one because the pilot was required to use all controls in a vigorous and positive manner to regain the runway after the aircraft had drifted off the line of flight because the ailerons were not equalized prior to takeoff. The takeoff was made with a slight amount, approximately 2-3°, of starboard wing down aileron applied. This condition was not apparent until the aircraft had attained approximately 20 ft of altitude, when it began to yaw and turn to the right. The wings were levelled and the turn ceased, but the angle of yaw remained constant and the aircraft proceeded along its original line of flight. It was immediately apparent that whatever directional stability was available from the rudder was being cancelled out by a directionally destabilizing moment imparted by the drag created by the elevator and its structure during yawed flight. Full left aileron was applied, together with full left rudder and partial (approximately the zero degree setting) nose down elevator. The aircraft responded slowly and the runway was regained. During this manoeuvre, which was made at approximately 37 mph IAS, the aircraft's response to rudder was poor; the rudder appeared to be partially stalled. The ailerons were effective but the initial response of the aircraft to full aileron deflection was slow; the rate of response was estimated to be 6° per second. The elevator was very effective; the control force required to move the elevator was very light — approximately 2-3 lb push force — and overcontrolling was difficult to prevent.

Minor damage was sustained by the aircraft during the landing because the throttle was closed too quickly. The aircraft ceased to fly at approximately 27 mph and dropped quite gently from about 4 ft onto the left wing skid, left wheel and nose wheel. There was no warning of the approach to the stall. The stall was manifest by a sudden, clearly defined increase in rate of descent. There was no tendency for the nose elevator to stall out ahead of the main wings — the elevator was set at approximately the +5° nose up mark on the indicator when the wings stalled. "Power on" approaches were made in all subsequent landings, with the exception of the final flight at Baddeck.

Weather conditions precluded further test flights until the 5th February when the following flights were made (the flights are numbered chronologically, with flights 1-4 on the 29th January):

No.	Duration of Flight	Distance Flown	Height	Wind
5	3 sec	110 ft	4 ft	10-15 kts
6	23 sec	850 ft	10 ft	10-15 kts
7	33 sec	1200 ft	15 ft	10-15 kts
8	43 sec	1600 ft	10 ft	10-15 kts

The lack of directional stability noted on the previous flights caused some concern. A vertical fin 12 ft in area was fabricated and installed ahead of the rudder for the flights on the 5th February. There was a marked improvement in directional stability and control. However, the fin was removed after the four flights noted above.

The flights on the 5th February were uneventful. The pilot had become more familiar with the aileron control system and its use had become instinctive. It was noted that if the final approach to landing was properly executed under conditions of partial power at about 32-33 mph, the aircraft tended to round-out automatically as the elevator encountered ground effect.

Surprisingly enough, the rudder control system presented the most difficulty to the pilot; a seemingly ineradicable tendency to push with the foot against the supporting cross member to initiate a turn was encountered! This tendency was overcome however, during the final 3-4 flights.

The ninth and final test flight was made from the ice at Baddeck on the 21st February. It was the best flight of the series and duplicated exactly, insofar as could be verified, Mr. McCurdy's original flight 50 years before. It was made under nil wind conditions and a distance of 2,100 ft was flown at a constant height of 20 ft. The duration of the flight was 41 seconds. The maximum speed attained was an indicated 43 mph, and it was noted that at this speed the aircraft was approaching a condition of static longitudinal instability. The onset of this condition is shown in the curve of Figure 9 labelled 'Flight'. This curve was plotted from observed elevator angles required for trimmed flight throughout the speed range 30-43 mph. The increase in nose up elevator angle required to maintain trimmed, level flight at 43 mph, over that required at 37-38 mph, was readily apparent.

The aircraft was considered airworthy if flight was limited to conditions of light winds and no gusts. It was easy to control in straight and level flight under such conditions and it was easily manoeuvred through shallow-banked turns. It was not possible, however, for the pilot to acquire a sense of 'feel' for the aircraft. The mechanics of the control system precluded the feed-back to the pilot of readily interpretable control forces, i.e. the ratio of lateral force that could be exerted by the pilot against the aileron control yoke to the force required to overcome the system friction and aerodynamic loads was so great as to obscure completely the feed-back of aerodynamic forces resultant from aileron deflection. The same condition was encountered with both the elevator and rudder control systems.

The curve of elevator angle versus control force required, Figure 7, was fully confirmed. Friction forces within the elevator control system during flight were very light (approximately 1 lb) and the force required to move the elevator throughout the range from +5° (nose up elevator) to −3° (nose down elevator) was, for all practical purposes, zero. Thus, the aircraft occasionally exhibited a porpoising tendency which was primarily pilot induced.

Ten flights were made on the aircraft during which a total airborne time of 3 minutes and 52 seconds was accumulated.

CONTROL OF TEMPERATURE VARIATION IN A PRESSURIZED INTERMITTENT WIND TUNNEL†

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SUMMARY

Developments in the field of supersonic wind tunnel testing have led in recent years to the use of large pressurized intermittent tunnels. Regulation of stagnation temperature is a problem peculiar to this type of tunnel because of the expansion of the air in the storage system and the consequent rapid decrease in the storage temperature during blowdown. A common method of temperature control has been the inclusion of a thermal storage medium inside the pressure tanks; this medium has a high thermal capacity and transfers heat to the air as it cools during expansion. In the present paper a theoretical analysis of blowdown with heat transfer is developed, resulting in a set of differential equations describing the temperature distributions in the storage vessels during the tunnel run. Numerical solutions to the differential equations have been obtained for various configurations of the air storage system for a 5 ft × 5 ft wind tunnel operating at 1.8 atmospheres stagnation pressure at a Mach number of unity. The results obtained in this paper allow an assessment to be made of the significance of various factors which affect the performance of thermal storage matrices. Some general rules for the optimization of such matrices are deduced from the numerical solutions.

INTRODUCTION

In recent years there have been considerable advances in wind tunnel testing techniques and increases in the speed of data recording and reduction. These changes have contributed to the development of a new type of supersonic wind tunnel — the large pressurized intermittent tunnel.

Intermittent operation allows a much larger test section area to be employed for a given powerplant size, and the energy accumulated slowly over a long charging period can be released rapidly during a short tunnel blowdown. Variation of model incidence during blowdown, according to a preselected program, and the use of automatic data processing equipment enables a series of measurements to be obtained during a single tunnel run. Furthermore, the pressure regulation afforded by the combination of a high pressure air storage and an automatic control valve permits variation of the tunnel mass flow in order to obtain a desired test section Reynolds number.

The advantages of the large pressurized blowdown tunnel, compared with the more conventional continuous and vacuum drive types, are so great that most of the large transonic and supersonic tunnels recently built or presently under construction fall into this class. The development of large intermittent tunnels is described in some detail in Reference 1 and a typical arrangement of such a tunnel is illustrated in Figure 1.

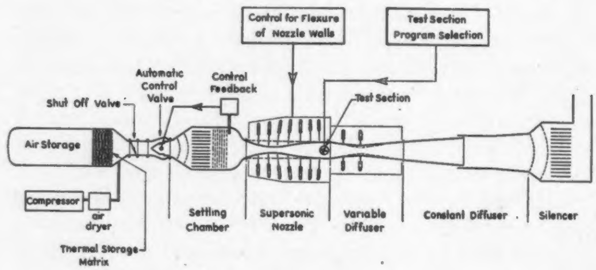

Figure 1
Schematic layout of pressurized intermittent wind tunnel

LIST OF SYMBOLS

A	matrix surface area (ft^2)
B	quantity defined by Eq. (18)
C	matrix specific heat (ft lb/ft^3 °R)
C_p	specific heat of air at constant pressure (ft lb/slug °R)
C_V	specific heat of air at constant volume (ft lb/slug °R)
E	kinetic energy (ft lb)
h	heat transfer coefficient (ft lb/ft^2 sec °R)
K	thermal conductivity of air (ft lb/ft sec °R)
L	total length (ft)
m	mass flow (slug/sec)
p	pressure (lb/ft^2)
Q	heat energy (ft lb)
Re	Reynolds number (dimensionless)
r	hydraulic radius (ft)
S	tank cross section (ft^2)
T	temperature (°R)
t	time (sec)
W	matrix weight (lb)

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x	axial distance (ft)
γ	ratio of specific heats
ρ	air density (slug/ft^3)
μ	viscosity coefficient (slug/ft sec)

Subscripts

i	initial
o	outlet
M	matrix
W	wall

SPECIAL PROBLEMS ASSOCIATED WITH PRESSURIZED TUNNELS

In the development of the modern wind tunnel many new and interesting design problems have been encountered and have, in various ways, been overcome. The large pressurized blowdown tunnel has its own associated problems, particularly in relation to the control of operating conditions.

The use of high pressure air storage tanks poses two special problems which are not encountered in vacuum drive or continuous tunnels. These are the control of tunnel stagnation pressure and the control of tunnel temperature. During blowdown the storage pressure decreases continuously and the expansion of the air remaining in the storage tanks causes a temperature drop which may amount to several hundred degrees Fahrenheit. Thus, any satisfactory pressurized blowdown tunnel must incorporate controls to regulate pressure and temperature in the test section.

The problem of temperature stabilization is discussed in some detail below, with special reference to the use of a thermal storage matrix in the air storage system.

METHODS OF TEMPERATURE STABILIZATION

Maintenance of correct tunnel temperature requires the addition of considerable energy to the airstream, and this must be done before the air reaches the test section. If heating coils are incorporated in the tunnel inlet, very high rates of power input are required because of the large mass flow, and a difficult control problem is introduced. It has been more common to employ a thermal storage medium consisting of a large amount of metal in, or at the outlet from, the pressurized storage tanks. This medium must have a large heat storage capacity and a large surface area over which the escaping air must pass. Heat transfer from the thermal storage medium to the air is sufficient to overcome most of the temperature drop suffered during the expansion process, so that the overall change in tunnel temperature during a blowdown can be reduced to a very few degrees.

Some wind tunnels have been built with a thermal storage matrix contained in a heat exchanger chamber external to the pressure storage vessels. This type of construction increases the overall size of the wind tunnel plant and has the further disadvantage that some form of regeneration may be required to reheat the matrix material between blowdowns. Analysis of the performance of this type of heat exchanger can be simplified because it may be assumed, with considerable justification, that the flow is incompressible and that the velocity is constant through the matrix. Furthermore, the inlet temperatures can be closely approximated by assuming an adiabatic expansion in the storage tanks. Reference 2 presents an analysis of this type of heat exchanger together with some experimental verification of the predicted temperatures. Reference 3 presents a similar analysis for a heat exchanger consisting of a set of parallel steel plates.

The idea of placing the thermal matrix inside the air storage vessels is attractive for three reasons. First, this scheme reduces the overall tunnel size, because no separate heat exchanger section is required. Second, regeneration of the thermal matrix can be achieved automatically by recharging the storage tanks between blowdowns with air at an elevated temperature. Third, the tunnel running time can be increased for the same initial storage pressure, because the average temperature of the air remaining in the storage tanks at the end of blowdown is higher. Performance calculations for this type of system are complicated because, with the matrix inside the storage vessels, neither constant pressure nor constant velocity can be assumed for the air flowing through the matrix. A general analysis of blowdown from containers with inserted heat capacitors is made in Reference 4 assuming that the thermal matrix can be treated as a single uniform-temperature heat exchanger.

One of the early applications of a large scale thermal storage matrix inside the pressure vessels was employed by North American Aviation[5] in their 7 ft × 7 ft blowdown tunnel at Los Angeles. The storage system for the North American tunnel comprises eight 36½ ft diameter spherical tanks connected in parallel. Each of these tanks was completely filled with ordinary tin cans to form a matrix with high surface-to-mass ratio. Preliminary performance tests of a similar matrix were made using a smaller experimental arrangement to establish the feasibility of the method. Many carloads of tin cans were required to fill the large tanks, but the final operation of the system was found to be quite satisfactory.

Subsequently, other tunnels, including the Boeing Aircraft 4 ft × 4 ft tunnel, were treated in the same manner using tin cans as a thermal storage matrix. Aoki[6] has presented a theoretical analysis of the performance of this type of matrix assuming zero temperature gradients through the tank and deduced average heat transfer coefficients for tin cans from the results of experimental blowdowns from a small pressure tank containing such a matrix.

A 4 ft × 4 ft tunnel recently completed by Convair[7] at San Diego, California, has an air storage system composed of six cylindrical tanks connected in parallel. A thermal matrix of alumina balls is located at the outlet of each tank.

CONFIGURATION OF AIR STORAGE SYSTEM

Due to the extreme annual temperature variations in Canada, it is essential that the air storage vessels for wind tunnels in this country be enclosed in a building.

Pressure tanks of various shapes have been considered, but spheres and cylinders appear to have the most practical possibilities. The amount of welding and stress relieving which would have to be done on the site is a deciding factor against the use of spheres. Furthermore, the building required to house a set of spheres is larger than that needed for a set of cylinders of equal capacity. A set of three cylindrical tanks form an arrangement

which can conveniently be enclosed in a building, but the most suitable method of interconnection and the optimum configuration of the thermal storage matrix are not readily apparent. The performance analysis described in this paper provides some useful answers to these problems.

The use of a tin can matrix in a cylindrical storage vessel was analyzed, and the performance was checked in an experimental arrangement, by Nazzer and Chisholm[8]. A manually operated control valve was used to maintain a constant pressure in a downstream plenum chamber, and the plenum outlet was regulated by an orifice plate. Air storage temperatures and pressures were recorded as a function of time. From these experiments an overall heat transfer coefficient for the arrangement was deduced.

Subsequently further performance figures for the can type of matrix were reported by Tucker[9]. These data were based on measurements taken in a 5 in × 5 in pilot tunnel at the National Research Council and indicated satisfactory temperature regulation.

Cost analysis of the combined thermal storage-air storage system shows that the addition of a thermal matrix increases the total cost in several ways. The cost of the matrix itself must be considered, together with the costs of installation and the necessary supporting structure. If the maximum tunnel running time is not to be shortened, the volume of the storage vessels must be increased to offset the pressure loss through the matrix. On the other hand, in the absence of a matrix, or with a matrix occupying only part of the storage tanks, additional volume may be required to compensate for the temperature drop of the air remaining in the storage system at the end of blowdown (the lower the final storage temperature, the greater is the air density and the more air remains unavailable for useful tunnel run). Finally, any increase in the storage capacity requires an increase in building size to accommodate the larger tanks.

Pressure loss data from the NRC pilot wind tunnel indicated that the axial loading on the tin cans during blowdown would be sufficient in a full scale tunnel to cause shifting and possibly deformation of the cans within the matrix. To overcome this problem a number of transverse screens or grids would be required to hold the matrix in position. Then, in order to fill the cylinders uniformly with cans, one or more manholes would be required between each pair of adjacent screens, thus considerably increasing the complexity and cost of the air storage system. Also, the excessively high pressure losses would require a large increase in storage volume.

USE OF TUBE MATRIX

Further consideration of the economics of installation suggests the adoption of a thermal storage matrix comprising many parallel tubes uniformly arranged to fill the tank cross section as shown in Figure 2. Compared with tin cans, such a matrix can be more easily installed and more simply restrained from shifting under aerodynamic loads, and the pressure losses are considerably lower.

The regular geometry of cylindrical tanks containing a tube matrix suggests the possibility of predicting the performance of the system from a theoretical standpoint, using empirically determined heat transfer coefficients for similar arrangements. An analysis of this kind would

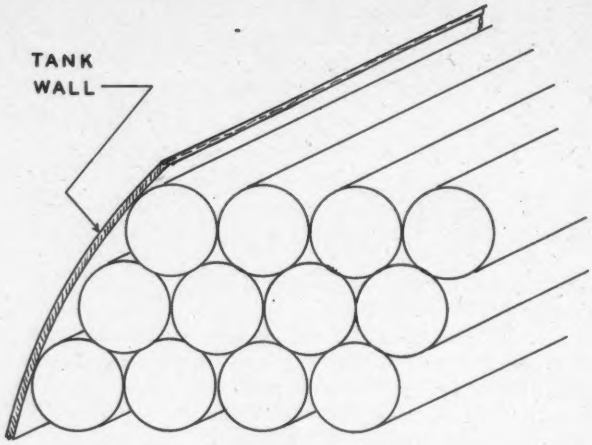

Figure 2
Arrangement of a tube matrix

provide a basis for design of a thermal matrix having adequate temperature control characteristics but without using unnecessary material or generating excessively high pressure losses.

The following theory for temperature control was developed primarily to optimize the storage tank and matrix configuration. One of the main objectives of the analysis was the examination of the relative merits of connecting the three storage tanks in series and in parallel. A further objective was the assessment of the importance of such parameters as matrix length, tube diameter and thermal capacity of the medium.

The method as outlined below permits performance comparisons between alternative geometrical configurations under the same blowdown conditions, and also allows temperature distributions in the air and in the thermal storage medium to be predicted as a function of time during a tunnel run.

THEORY

The analysis presented here is confined to the case of pressure tanks of cylindrical cross section and thermal storage matrices of uniform density. However, the theory can be generalized to account for tanks of non-uniform cross section provided that one-dimensional flow can be assumed (spherical tanks are thus excluded). Generalization to cover thermal matrices of non-uniform density is also possible if suitable definitions of the local heat transfer coefficient can be made. For simplicity in the present analysis both mechanical and heat energy will be expressed in mechanical units (ft lb).

Consider a cylindrical tank of length L and cross-sectional area S as shown in Figure 3. A length L_M at the outlet end of the tank is filled with heat storage material, uniformly distributed and having a total surface area A sq ft and a total weight W lb.

Suppose that everywhere in the tank the air is initially at pressure P_1, temperature T_1, and density ρ_1, and that the thermal storage matrix and tank walls are also at temperature T_1. The control valve at the tank outlet is assumed to maintain the outlet mass flow at a constant value m_o during blowdown. One dimensional flow is assumed.

If the mass flow is assumed to originate uniformly

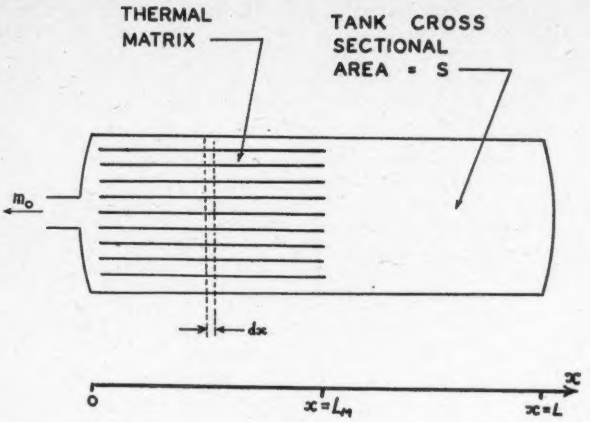

Figure 3
Cylindrical air storage vessel

from all portions of the tank, then each tank element acts as a mass flow source. For a cylindrical tank this implies that the mass flow is a linear function of axial position:

$$m = m_o\left(1 - \frac{x}{L}\right) \tag{1}$$

If the density of the air is assumed to be independent of position but to vary with time:

$$\rho = \rho_i - \frac{m_o t}{LS} \tag{2}$$

Now consider an element of the tank of length dx as shown in Figure 3. An energy equation for this small volume can be derived by summing all the energy gains and losses through the surfaces of the element and equating this sum to the change in energy content of the air within the element. In time dt the total flow of energy through the surface of the element, considering the contained matrix area as part of the surface, is

$$dQ = \frac{\partial}{\partial x}(mC_pT)\, dtdx + \frac{\partial}{\partial x}\frac{\partial E}{\partial t}\, dtdx + \frac{\partial Q_W}{\partial t}\, dt + \frac{\partial Q_M}{\partial t}\, dt \tag{3}$$

The first term of Eq. (3) represents the net loss of energy due to the difference between mass flow rates and temperatures at the upstream and downstream faces of the small cylindrical element. Since part of the total mass flow originates in the element, the inflow at the upstream face will be smaller than the outflow at the downstream face. Also, the incoming air will be colder than the outgoing air.
Then, substituting from Eq. (1)

$$\frac{\partial}{\partial x}(mC_pT) = C_p m_o\left[\left(1 - \frac{x}{L}\right)\frac{\partial T}{\partial x} - \frac{T}{L}\right] \tag{4}$$

The second term of Eq. (3) represents the difference in the kinetic energy of the air entering and leaving the element. The kinetic energy flux through any tank cross section is:

$$\frac{\partial E}{\partial t} = \frac{m^3}{2\rho^2 S^2} \tag{5}$$

Then, substituting from Eq. (1)

$$\frac{\partial}{\partial x}\frac{\partial E}{\partial t} = -\frac{3m_o^3(L - x)^2}{2\rho^2 S^2 L^3} \tag{6}$$

The third and fourth terms of Eq. (3) account for the heat transfer from the tank wall surrounding the element and from the matrix material contained in the element respectively. These terms can be expressed as:

$$\frac{\partial Q_W}{\partial t} = h\sqrt{4\pi S}\,(T_i - T)dx \tag{7}$$

$$\frac{\partial Q_M}{\partial t} = \frac{hA}{L_M}(T_M - T)dx \tag{8}$$

The heat transfer coefficient, h, may have a different form in the two terms, depending upon the flow conditions. In writing Eq. (7) it is assumed that the storage cylinder walls, because of their massive nature and the short running time, remain at the initial temperature during blowdown. The matrix temperature, however, is assumed to be a function of both x and t.

Eq. (3) can now be written:

$$dQ = \frac{C_p m_o}{L}(L - x)\frac{\partial T}{\partial x}\, dtdx - \frac{C_p m_o T}{L}\, dtdx - \frac{3m_o^3(L - x)^2}{2\rho^2 S^2 L^3}\, dtdx$$
$$+ h\sqrt{4\pi S}\;(T_i - T)dxdt + \frac{hA}{L_M}(T_M - T)dxdt \tag{9}$$

The total change dQ in the energy content of the volume element, as expressed in Eq. (9), manifests itself as changes in the internal and kinetic energy of the air in the volume, i.e.

$$dQ = d\left[\left(C_V T + \frac{m^2}{2\rho^2 S^2}\right)\rho S dx\right] \tag{10}$$

which can be expanded to the form

$$dQ = C_V\rho S dT dx + C_V T S d\rho dx - \frac{m_o^3(L - x)^2}{2\rho^2 S L^2}\, d\rho dx + \frac{mdmdx}{\rho S} \tag{11}$$

Eqs. (9) and (11) can now be equated. After simplification this yields the following expression:

$$\rho\frac{\partial T}{\partial t} = \frac{\gamma m_o}{SL}(L - x)\frac{\partial T}{\partial x} - \frac{(\gamma - 1)m_o T}{LS} + \frac{2h}{C_V}\sqrt{\frac{\pi}{S}}\;(T_i - T)$$
$$+ \frac{Ah}{L_M S C_V}(T_M - T) - \frac{m_o^3(L - x)^2}{\rho^2 S^3 L C_V} \tag{12}$$

If the matrix specific heat is C and if axial heat conduction within the matrix is neglected, then the matrix heat balance equation is:

$$(CSdx)\frac{\partial T_M}{\partial t} = -\frac{\partial Q_M}{\partial t} = -\frac{hA}{L_M}(T_M - T)dx \tag{13}$$

Then

$$\frac{\partial T_M}{\partial t} = -\frac{hA}{CSL_M}(T_M - T) \tag{14}$$

Eqs. (12) and (14) are a pair of partial differential equations, the simultaneous solution of which will yield T and T_M as functions of x and t. The notation $T\ (x, t)$ and $T_M\ (x, t)$ will be used to designate temperatures existing at position x and time t.

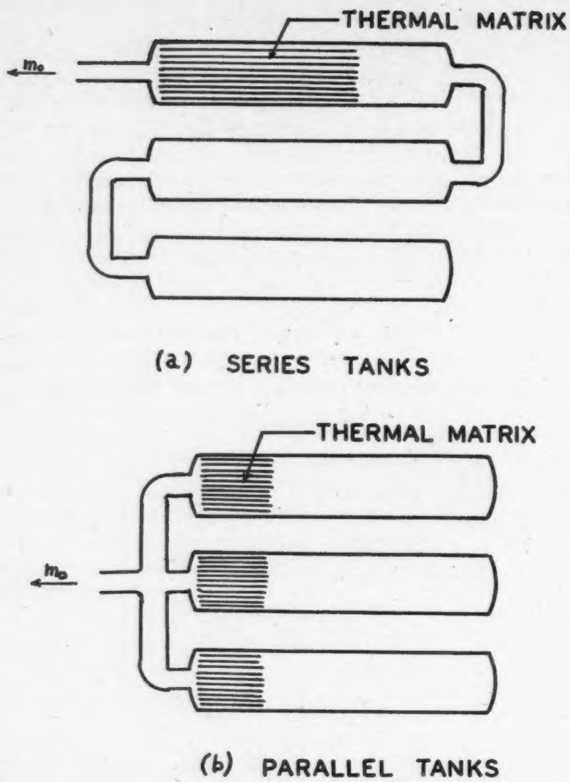

Figure 4
Configuration of three tank air storage system

For fully developed turbulent flow the heat transfer coefficient in a channel of hydraulic radius r may be written in the following empirical form[10].

$$h = \frac{0.027K}{4r} Re^{0.8} \tag{15}$$

where K is the thermal conductivity of air and the Reynolds number, Re, is based on hydraulic radius and air velocity U;

$$Re = \frac{4r\rho U}{\mu} \tag{16}$$

The hydraulic radius is defined as the ratio of cross sectional area to wetted perimeter; i.e. $r = SL_M/A$. Furthermore $\rho U = m/S$ so that Eq. (16) becomes:

$$Re = \frac{4L_M m_o(L - x)}{\mu AL} \tag{17}$$

We may define a quantity B which is a function of position but not of time:

$$B = 0.0065 \frac{KA^2}{S^2 L_M^2 C_V} Re^{0.8} \tag{18}$$

Order of magnitude analysis indicates that the last term of Eq. (12) is negligible with respect to the other terms. Also, for storage tanks of large diameter, heat transfer from the tank walls can be neglected relative to heat transfer from the thermal matrix. Under these conditions, and substituting from Eq. (18), Eqs. (12) and (14) become:

$$\rho \frac{\partial T}{\partial t} = \frac{m_o}{LS}\left[\gamma(L - x)\frac{\partial T}{\partial x} - (\gamma - 1)T\right] + B(T_M - T) \tag{19}$$

$$\frac{\partial T_M}{\partial t} = \frac{BC_V}{C}(T_M - T) \tag{20}$$

These two equations cannot be solved analytically because of the dependence of B upon x. However, numerical step-by-step integration in space and time can be employed if several axial stations are chosen and temperatures are calculated at time intervals Δt. The initial temperature distributions are known:

$$T(x, o) = T_M(x, o) = T_i \tag{21}$$

Then $\partial T/\partial t$ and $\partial T_M/\partial t$ at $t = 0$ can be calculated for each station from Eqs. (19) and (20) and, knowing these rates, values of $T(x, \Delta t)$ and $T_M(x, \Delta t)$ can be obtained at each station. Eqs. (19) and (20) can then be solved again to obtain new rates of temperature drop at each station. The following difference equations are used:

$$T(x, t + \Delta t) = T(x, t) + \frac{\partial T}{\partial t}(x, t)\,\Delta t$$

$$T_M(x, t + \Delta t) = T_M(x, t) + \frac{\partial T_M}{\partial t}(x, t)\,\Delta t$$

$$\frac{\partial T}{\partial x}(x, t) = \frac{1}{2\Delta x}[T(x + \Delta x, t) - T(x - \Delta x, t)] \tag{22}$$

In order to simplify the numerical calculations, use can be made of the fact that the air in the volume upstream of the thermal matrix expands adiabatically. This provides a boundary condition at the inlet to the matrix which can also be obtained by solving Eq. (19) in the absence of the matrix:

$$T(L_M, t) = T_i\left(\frac{\rho}{\rho_i}\right)^{\gamma - 1} \tag{23}$$

NUMERICAL CALCULATIONS

Using a matrix composed of circular tubes stacked as shown in Figure 2, the greater part of the flow will pass through the inside of the tubes, but some will pass through the small passages between tubes. The resistance of the small passages will be much greater and the heat transfer will be less effective than for the insides of the tubes.

In the present analysis these phenomena have been considered by assuming that the flow velocity is the same in both types of passage but that only 10% of the outside area of the tubes is effective as heat transfer surface. Thus the effective surface area of the matrix is 55% of the geometrical surface area.

Although the method can easily be generalized to treat series-parallel combinations of storage tanks, the present paper treats only pure series and pure parallel connections as shown in Figure 4. In order to reduce these arrangements to the simple form shown in Figure 3, it is assumed that the effect of the interconnecting pipes and fittings can be neglected. Then the three tanks can be represented by an equivalent single tank with the same axial velocity distribution. For the series arrange-

ment of Figure 4(a), the equivalent storage has the cross section of a single tank but three times the length of a single tank. For the parallel tanks of Figure 4(b), the equivalent storage has the length of a single tank but three times the single tank cross section.

The three tanks considered in the numerical calculations each have 11½ ft inside diameter and 140 ft length. An initial storage pressure of 20 atmospheres and an initial temperature of 545° R are assumed. A constant mass flow of 2,200 lb/sec, corresponding to 1.8 atmospheres stagnation pressure at a Mach number of unity in a 5 ft × 5 ft test section, is used in all the calculations.

Five different matrix and tank configurations were used in the calculations and these are listed in Table 1.

Cases A, C and E are all series combinations with 120 ft of thermal storage matrix. Cases A and E have the same total matrix surface area but different matrix weights, while cases C and E have the same total weight but different surface areas. Case D is identical with case A in all respects except that the matrix length is reduced to 60 ft by using tubes of smaller diameter. Case B is a parallel configuration with 20 ft of thermal matrix, the matrix being identical in all other respects with that of case D. The matrix surface area is the same for all cases except case C, and the wall thickness of the tubes is the same for all cases except case E.

A program was written for the solution of Eqs. (19), (20) and (22) on the Ferut Digital Computer at the University of Toronto Computation Centre, and numerical results were obtained in this way. Some of the calculations were also done by desk computer.

NUMERICAL RESULTS

The general results of the numerical calculations are illustrated in Figure 5. The outlet air temperature, $T(o, t)$ is shown for each configuration considered, and the adiabatic temperature drop, which would occur in the absence of any matrix, is indicated for comparison. It can be seen from Figure 5 that all the configurations restrict the overall temperature drop to less than 20°F for a 20 second run. However, there is a considerable difference between the effectiveness of individual configurations.

TABLE 1
ARRANGEMENTS CONSIDERED IN NUMERICAL CALCULATIONS

Case	A	B	C	D	E
Tank arrangement	series	parallel	series	series	series
Equivalent tank length L (ft)	420	140	420	420	420
Matrix length L_M (ft)	120	20	120	60	120
Matrix effective area A (sq ft)	590,000	590,000	792,000	590,000	590,000
Matrix total weight W (lb)	330,000	330,000	441,000	330,000	441,000
Matrix tube diameter (in)	1.0	0.5	0.75	0.5	1.0
Matrix tube wall thickness (in)	0.015	0.015	0.015	0.015	0.020
Equivalent tank cross section S (sq ft)	104	312	104	104	104
Matrix density (lb/cu ft)	26.6	53.2	35.4	53.2	35.4
Matrix area density (sq ft/cu ft)	47.6	95.3	63.5	95.3	47.6

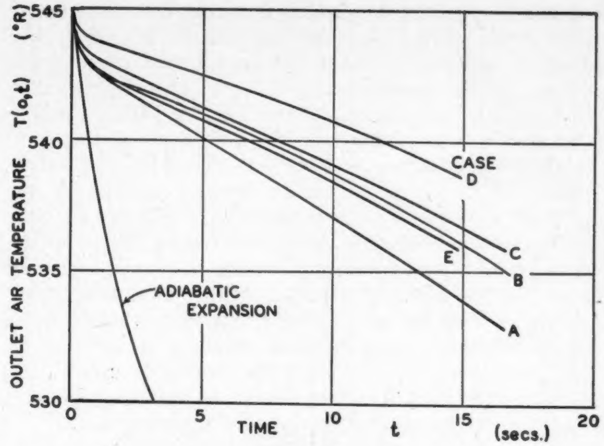

Figure 5
Variation of outlet air temperature for the five configurations considered

Some insight into the blowdown process may be gained from Figure 6 which shows the variation of the air temperature $T(o, t)$, and the matrix temperature, $T_M(o, t)$, at the outlet end of the tank in case B. Initially, in the absence of any temperature difference between matrix and air, the air cools adiabatically and the matrix loses no heat at all. As the temperature difference increases, so does the heat transfer rate, the rapid decline of the air temperature is arrested and the matrix temperature starts to fall. After approximately one second an equilibrium temperature difference is established between matrix and air and is maintained nearly constant throughout the remainder of the run.

Figure 7 shows the axial temperature distribution in the air and in the matrix at 16.6 seconds after the start

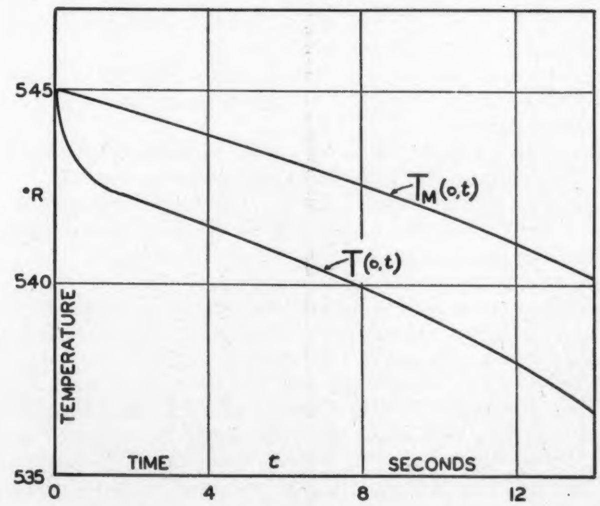

Figure 6
Variation of air and matrix temperatures at storage outlet for case B

of blowdown in case C. It is apparent that the greater part of the energy has been supplied to the air by the material at the inlet end of the matrix, while that at the outlet end has contributed very little. This suggests that matrix C is unnecessarily long. On the other hand, if the matrix is quite short the rapid energy loss and consequent loss of effectiveness of the inlet end of the matrix soon throws an added burden on the material at the outlet end. The result of insufficient length can be seen in Figure 5 as a gradual increase in the rate of temperature drop for the short matrix in case B. Figure 8 further illustrates the effect of matrix length by comparing cases A and D during a 10 second run. These cases have identical thermal capacities and surface areas but case D has been compressed to half the length of case A by reducing the tube diameter. It can be seen that the decrease in length improves the matrix performance.

The effect of greater thermal capacity, achieved by increasing tube wall thickness, is shown in Figure 9. Case E represents a 33% increase in thermal capacity over case A, all other matrix parameters remaining constant. The performance improvement thus gained requires the addition of 33% extra material. The effect of increasing surface area is shown in Figure 10 by comparing cases E and C, both of which have the same length and total matrix weight. Case C has 33% more surface area, achieved by reducing tube diameter and wall thickness, the quantity of material used remaining unchanged.

Figure 11 compares the parallel tank configuration of case B with the series tank configuration of case D. The identical matrix is used in both cases, the 60 ft length of case D being divided into three 20 ft lengths for case B. The comparison indicates much improved performance from the series connection.

CONCLUSIONS

Since the theory developed above accounts for axial variation of air velocity, air temperature and matrix temperature through the heat exchanger, it provides an insight into matrix performance which is lacking when internal gradients are neglected. The numerical results obtained provide useful comparisons between the performance of several air storage configurations and indicate the significance of various matrix parameters which influence temperature stabilization.

Two important conclusions respecting the storage system configuration can be drawn from the numerical results above:

(1) Series connection of the tanks provides better temperature regulation than does parallel connection.
(2) For a given thermal capacity and surface area a short matrix near the outlet is more effective than a long matrix distributed further along the tank.

It can be further concluded that, for blowdowns of short duration such as those considered here, temperature control is more sensitive to changes in matrix surface area than to changes in total thermal capacity. Although Figures 9 and 10 show the two effects to be of comparable magnitude, increase of tube wall thickness will result in a greater portion of the heat energy being stored in elements of the material remote from the heat transfer surfaces. This energy will not have time to flow to the surface during the short blowdown period. Thus, it is important that the surface-to-volume ratio of the matrix material should be high. As the length of run increases, the effect of thermal capacity should become more significant.

Application of the general configurational rules deduced above must be combined with consideration of other factors, such as pressure loss through the matrix. If tube wall thickness is reduced too much, the bottom tubes in the matrix will deform or crush under the weight of the tubes above.

The observations regarding long matrices suggest that many existing wind tunnels employ excessively large thermal storage matrices. Examination of Eq. (19) shows that matrix material at the end of the storage system remote from the outlet will contribute very little to temperature control. The flow velocity and, hence, the heat transfer will be low in this region. The unnecessary material included in such matrices would merely contribute to increased pressure losses and reduced running time.

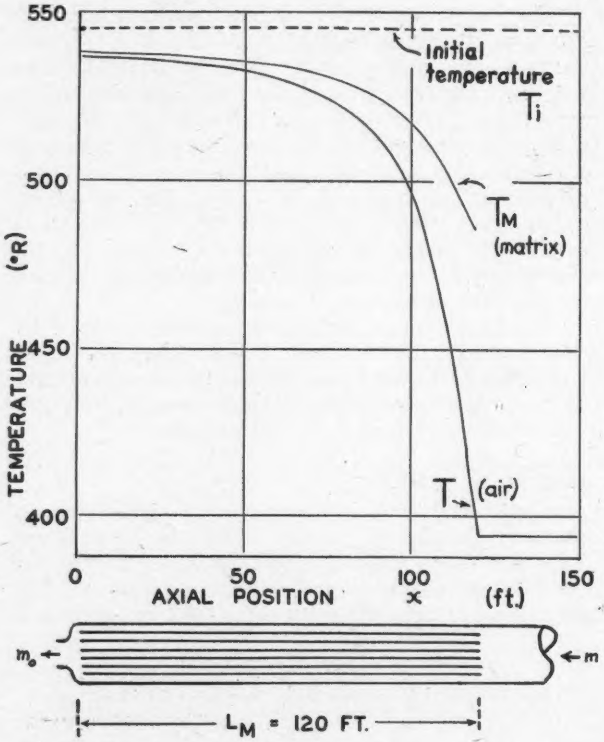

Figure 7
Axial temperature distributions after 16.6 seconds blowdown (case C)

Regeneration of a thermal storage system takes place as the pressure tanks are recharged. The temperature of the incoming air can be regulated so that when pressurization is complete the thermal matrix is once again at the same temperature as the storage air. Regeneration is discussed in some detail in Reference 11.

It is of interest to note that the inverse problem, the temperature rise during compression in the low pressure vessel of a vacuum driven blowdown tunnel, has been reported[12]. In this case the walls of the vacuum chamber absorb some heat from the air, thus lowering the pressure and increasing the tunnel running time.

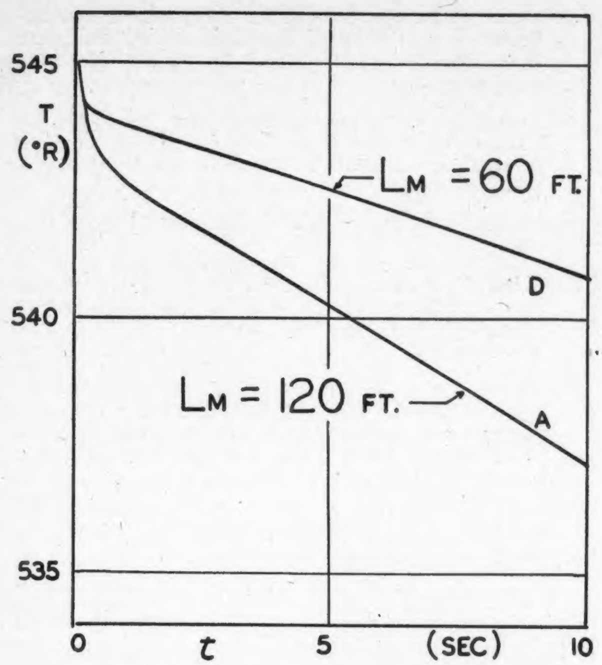

Figure 8
Effect of matrix length on outlet temperature variation

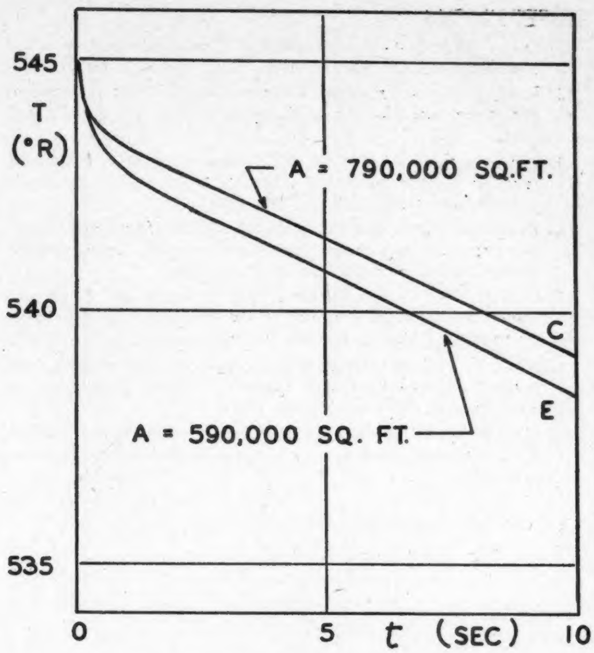

Figure 10
Effect of 33% increase in matrix surface area on outlet temperature variation

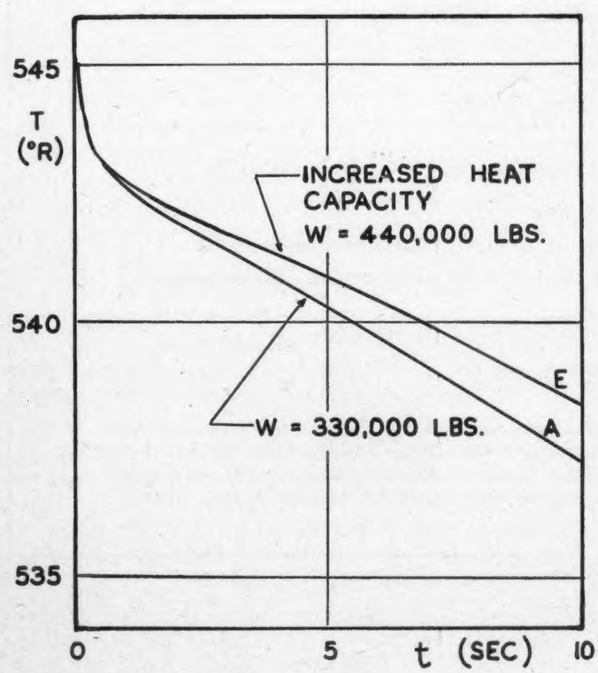

Figure 9
Effect of 33% increase in thermal capacity on outlet temperature variation

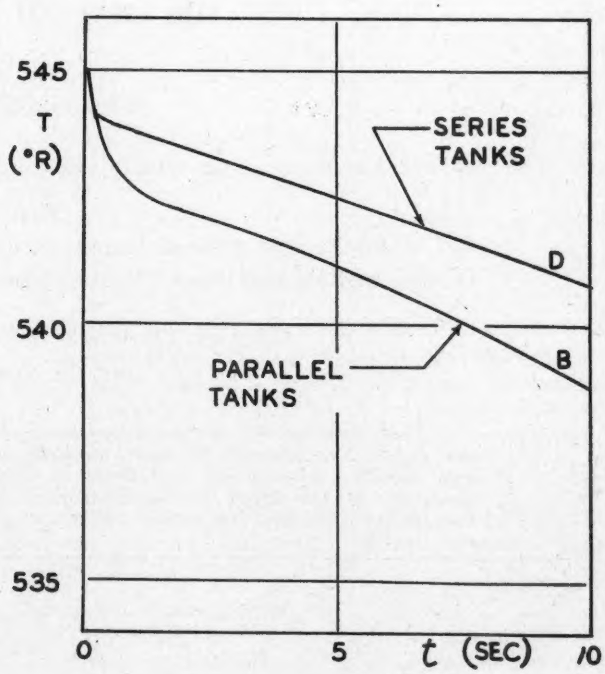

Figure 11
Outlet temperature variation for series and parallel tank arrangements

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ANNUAL GENERAL MEETING

The Annual General Meeting of the Institute will be held at

THE CHATEAU LAURIER, OTTAWA

on the

24th and 25th May, 1960

The Programme, which is now being prepared, will include Sessions on

Man in Space
Air Freight (Cargo handling, Freighter design, Northern logistics)
Design and Manufacture (Miniaturization, Small run production, Management)

as well as the annual Business Meetings of the Institute and the Specialist Sections.

This meeting affords an opportunity for the presentation of papers by members of the C.A.I. The Council is most anxious to encourage Canadian papers and hopes that any member wishing to contribute to any of the above-mentioned Sessions will submit a summary of his paper for consideration. Such summaries must be in the hands of the Secretary by the 31st December, 1959.

CANADIAN AVIATION — THE FIFTIETH YEAR†

by S/L R. G. Christie*

Royal Canadian Air Force

THE purpose of my paper is to review the "state-of-the-art" of Canadian aviation in 1959. This best can be done by dividing Canadian aviation into three divisions – Civil, the Industry, and Military.

CIVIL AVIATION

First, let us review the status of civil aviation. Civil aviation comprises the air transport services and private flying. The former are grouped into two broad classes: scheduled and non-scheduled services. The latter includes business and executive flying as well as that conducted solely for pleasure.

Air transport services

In 1959, seven major airlines in Canada are licensed to operate scheduled services. These are Trans-Canada Air Lines, Canadian Pacific Air Lines, Limited, Trans-Air Limited, Maritime Central Airways Limited, Pacific Western Airlines Limited, Quebecair Incorporated and Austin Airways Limited. In addition, there are 16 Commonwealth and foreign air carriers holding valid Canadian operating certificates and licences covering international scheduled commercial air services into Canada. Further, there are numerous small companies involved in the non-scheduled field that serve those areas of Canada that require air transportation but that do not warrant full-time service.

To illustrate the volume of business being conducted by Canada's air transport services, it is interesting to note that in 1957, the latest year for which complete statistics are available, these carriers flew 100.7 million miles. During this period, the number of revenue passengers carried increased 12% over 1956 to a high of 3.7 million. Of this total, TCA carried 1.895 million and CPAL .285 million. The trend of the travelling public is away from public surface transportation and 1959 should show an even greater increase in air travel than in the years immediately past.

Besides serving the domestic needs, Canadian scheduled carriers are now operating into four continents. Non-scheduled operators may be found to operate, on occasion, in all parts of the world.

†Based on a paper read at the Annual General Meeting of the C.A.I. in Ingonish, N.S., on the 17th June, 1959.

*Directorate of Air Defence Operations.

Government air transport policy

Detailed investigations and hearings over the past year have brought a general definition of the present government's policy towards air transportation, and a long term pattern for over-all development of these services in Canada should emerge within the near future. Results to date have indicated a move toward fairly wide competition in the light aircraft and helicopter fields and the introduction of quite limited competition over a portion of the scheduled transcontinental network. Currently under study is the status of regional carriers.

Business and executive flying

The growth of business and executive flying in recent years has been tremendous. Evidence of expansion in this field of civil aviation is the increase in number of non-commercial aircraft registered with the Department of Transport for operation in Canada. Over the past two years, private registrations have climbed from 1,780 to a total of 2,551 aircraft for March of this year. It is estimated that just over 600 of these may be classified as business and executive aircraft.

This total of 2,551 aircraft includes the full range from the light single-engined aircraft flown by its owner-pilot, to the full scale transport operations of large corporations involving a fleet of heavy twin and multi-engined aircraft flown by professional aircrews. In the next two years we can expect to see in operation the high speed, pure jet executive aircraft.

It is significant to note that business aircraft operators do not claim that this form of travel is more economical than the available commercial air or ground modes of transportation. Rather, the main attraction is availability, direct routing and speed. From this stems such attributes as convenience, time saving and increased on-the-job manhours. Public transportation cannot compete in this respect with well organized, efficient business flying operations.

Private and pleasure flying

In the field of private or pleasure flying, during 1957, 1,808 students took advantage of the government scheme of financial assistance for private flying training. During 1958, this number increased to 2,317. Approved courses of this type are conducted by 90 training establishments,

comprising 51 flying clubs of the Royal Canadian Flying Clubs Association and 39 commercial flying schools of the Air Industries and Transport Association.

Further evidence of the increased usage of civil aircraft is the statistics provided by DOT on takeoffs and landings. In February of this year alone, Montreal's Dorval Airport, busiest of Canada's major air facilities, had 23,945, closely followed by Ottawa, Toronto, Edmonton, Vancouver and Winnipeg. Montreal also led all other airports with a total of 4,543 arrivals and departures by scheduled airlines. Total traffic at all DOT airfields was up 16% over the same period in 1958.

Thus, in summary, Canadian civil aviation in 1959 is continuing to grow with no sign of any let-up in its current expansion.

THE INDUSTRY

I am sure you will agree with me that 1959 – the Fiftieth Year – will be a year to remember as far as the aviation industry is concerned. The cancellation of Canada's most ambitious military weapons system – the Arrow – has had far reaching effects on the sub- and prime contractors supporting the aviation industry of this country. However, this is not the first time that our industry has felt the "knife-at-the-throat" and, if history repeats itself, it may not be the last. Changing economic and military conditions have dictated similar actions in the past, but, despite the gloom expressed in the period immediately following such events, our aviation industry has always surged back and regained a position of prominence in Canada's industrial complex. Indications of this ability to recover from states of depression is evident throughout the history of the industry. You may say that this time the situation is different but this has all been said before and proven to be incorrect. Let me quote a few examples. After a peak production period in 1944 when 427 million dollars flowed into the industry, the figure fell to 55 million in 1950. However, the figure again climbed in 1955 to 354 million, largely as a result of an all-Canadian long-range fighter for North American Air Defence and the production of several types of defence aircraft built in Canada from foreign designs for NATO and other military purposes. Although many of these programs have been completed or terminated, others have commenced to take their place. Unfortunately, the contracts on hand in 1959 are insufficient to keep a large portion of Canada's aviation industry fully employed. However, industry must not despair. This may sound easy for a Service officer to say as neither my position nor my source of income has been immediately affected. Rather, I base my reasoning for optimism on recent announcements regarding a replacement fighter-bomber for our Sabre aircraft in Europe; the small but nevertheless significant announcement on June 15th for the US Navy's Grumman Tracker that will have a Canadian content of approximately 40%; and the announcement during the year that the US government has revised the "Buy American" Act, thus allowing Canadian contractors to bid competitively with American sources on defence contracts for the US. In the case of the last mentioned source of revenue, I personally feel that the success of this opening for the Canadian aviation industry is wholly in the hands of Canadian manufacturers, for it has always been true that high quality at a minimum cost is the keynote to success in any field of merchandising.

Fortunately, the aviation industry has not depended entirely on defence programs. Several types of civilian aircraft have been developed to meet Canadian flying needs and conditions and, besides the Canadian market, these products have met with good response from users abroad.

Current production status

For the benefit of those not fully familiar with the production status of the Canadian aviation industry, I will briefly outline some of the main programs on hand.

Canadair CL-28 or Argus

More than 30 of these large four-engined maritime reconnaissance aircraft have been ordered and over half of these will have been delivered by the end of 1959. Current orders should keep the production shops working until 1960.

Canadair CL-44

Another four-engined aircraft that is a descendant of the Argus, this aircraft has been ordered for long-range transport purposes by the RCAF. None will be delivered in 1959 but the first production aircraft is undergoing joint company-RCAF trials. A swing-tail version of this design appears to have considerable potential as a commercial air freighter. As evidence, Canadair has received a 70 million dollar order for this configuration from Flying Tigers, and Seaboard and Western in the United States.

Canadair 540 or Cosmopolitan

This is the familiar Convair 440 equipped with the Napier Eland turboprop powerplant. Ten of these aircraft are on order for the RCAF and a company demonstrator has conducted an extensive sales campaign in North and South America. Although Canadair has not announced the results of this program, civil transport sales prospects appear good.

Canadair CL-41

A jet trainer, this project is now under development and the first Pratt and Whitney JTC-12 powered model is being prepared for demonstration. This aircraft is a private venture, begun originally on the assumption that the RCAF might introduce all-through jet training to its pilot training curriculum.

CF-104 or Starfighter

This will be a Canadian-built version of the famous Lockheed F-104 Starfighter which has been ordered to replace the Sabre aircraft of the RCAF's No. 1 Air Division in Europe. The airframe will be built by Canadair and the engine by Orenda. A high percentage of the electronic equipment selected for the CF-104 will be built in Canada.

De Havilland Beaver

Little new can be said about the versatile Beaver. Over 1,300 of these aircraft have been sold to date and production is assured at least through 1959. A high percentage of the Beavers produced have been purchased by the US Defense Department but civil sales have been good and are continuing on a reduced scale both at home and abroad.

De Havilland Otter

Like its smaller partner, the Beaver, this aircraft has been sold in quantity to the US military services with the RCAF being second in sales source. With more than 300 produced, the Otter is still very much in demand and should be in production for at least another year.

De Havilland Caribou

Now well into its test flight program, the Caribou is showing considerable promise. Five of these aircraft are on order for evaluation purposes by the US Army and all five aircraft will be delivered by the end of this year. An additional aircraft is on order for evaluation by the Canadian Army. Although no firm civilian orders are on hand, an extensive demonstration tour is being conducted in Europe for NATO and this tour will continue through the Middle and Far East late this year and into 1960.

De Havilland CS2F-1 Tracker

This Grumman-designed anti-submarine aircraft is now in its fourth year of production under license at De Havilland Aircraft of Canada. Current production orders at the present rate of construction are sufficient to keep the Tracker line going until mid-1960.

Avromobiles

Still highly secret, this new concept of flight has received considerable attention in our national press. Versions of this new family known as Avrocar, Avrocoach and Avrotruck may very well become household names in the near future.

Industrial summary

Thus, a quick review of industry in 1959 indicates that, despite increased sub- and prime contractors facilities, there is a definite lack of large-scale production programs on hand. Many parties within and without the aviation industry feel that again we have reached a state of depression. However, in fact, the new CF-104 program and other projects under consideration for both foreign and domestic markets make the year 1960 and the years beyond ones of potential promise. Success or failure, indeed the very survival of our aviation industry may well depend on the ability of the industry to sell abroad. In many respects this ability is entirely up to the industry itself.

MILITARY

Military aviation has, in the past, been the prime source of business for most of the aircraft constructors in Britain and North America. However, recent advances in the field of missiles have caused governments to reconsider their proposed expenditures on manned military aircraft. Whether the manned aircraft will have an operational role to play in future warfare is the subject of considerable debate. Although it can be said with some degree of certainty that certain phases of military aviation, such as transport and maritime, will continue with manned aircraft indefinitely, many believe that the tasks of air interception and bombardment will soon be allocated to the missile. The impact of this re-assessment during the Fiftieth Year has been tremendous. Companies that up to this year seemed assured of many years of military contracts for manned aircraft are now faced with the necessity of changing to new fields of endeavour or going out of business. The price of military progress has been high to the aviation industry.

Current military roles and equipments

Briefly, I would like to review the air roles of the Canadian Armed Forces and the equipments that they are using in this Fiftieth Year.

Navy

The role of the Royal Canadian Navy within NATO is to supply a small but highly efficient anti-submarine force with research and development directed particularly to the hunting and destruction of submarines.

Heart of the naval air task force is the HMCS Bonaventure, the first Canadian-owned aircraft carrier. This ultra-modern ship is equipped with the latest facilities for the handling of the fighting aircraft of Canada's fleet. Aircraft currently employed on this carrier are the Canadian-built Trackers which are utilized for anti-submarine patrol, Banshee twin-jet, all-weather fighters equipped with the Sidewinder missile for carrier protection and Sikorsky helicopters for rescue operations.

Army

The role of the aviation section of the Canadian Army is to supply reconnaissance, liaison and light cargo services for the artillery, field headquarters and the Army Service Corps.

In 1959, this role was conducted with L-19's and light helicopters. These aircraft are divided between two Air Observation Post Flights, one at Camp Shilo, Manitoba, and one at Camp Petawawa, Ontario, and the light Aircraft School at the Canadian Joint Air Training Centre, Rivers, Manitoba. Prior to 1959, the RCAF has been largely responsible for the maintenance and air worthiness of these aircraft. However, commencing this year, the Army has taken over the complete operation of these equipments with the exception of the logistic support which is still vested in the RCAF.

Air Force

Basically, the role of the RCAF can be stated in three parts:

(1) To supply air defence forces to NORAD for the protection of North America.

(2) To supply air defence forces in Europe and maritime forces in the Atlantic for the support of NATO.

(3) To provide air services in support of the various Canadian commitments to the United Nations.

In 1959, the RCAF has approximately 2,000 aircraft operating in five commands and one air division. A short review of the activities of the major operational elements is as follows:

Maritime Air Command

Maritime Air Command assumed new stature, in May 1958, when it took delivery of the first CL-28 Argus maritime patrol aircraft, widely regarded as the finest anti-submarine aircraft currently in service in the world. This long range aircraft demonstrated its capabilities during the Fiftieth Year by flying non-stop from Nova Scotia to Ireland and return and, on October 2nd, establishing a new Canadian long range record when, while returning from a good-will trip to Australia and New

Zealand, an Argus flew from Honolulu to North Bay, a distance of 4,570 miles. In addition to the Argus, Maritime Command continues to operate the shorter range Neptune aircraft. The introduction of new aircraft and equipments on maritime operations reflects the growing recognition being given by defence planners to the submarine threat.

No. 1 Air Division

The 6,200-man Air Division, operating eight squadrons of Sabre 6's and four squadrons of CF-100's, continues to meet Canada's NATO commitments in Europe. The standard of training and performance remains high but the Air Division's effectiveness is rapidly diminishing in direct proportion to the aging of its aircraft. The government's announcement in early July that the Sabres would be replaced by the Canadian-produced CF-104 Starfighter has assured a continuing support of NATO in Europe with this ultra-modern, supersonic fighter bomber.

Air Transport Command

ATC can look forward to a future of increasing activity in which growing demands for its service will be met with new equipments in the form of two new types of turboprop transports, both currently being built by Canadair Ltd. These are the long range CL-44 military transport and the short-medium range CL-66. During 1959, ATC continued to operate Comet, North Star, C-119 and Dakota aircraft in support of National Defence requirements both domestically and overseas. This fall, coincident with the move of Training Command HQ from Trenton to Winnipeg, ATCHQ was moved from Lachine to Trenton.

Air Defence Command

The nine CF-100 squadrons, the muscle arm of Canada's Air Defence Command, this year commenced their fifth year of full operation. Plans are continuing for the introduction of Bomarc missiles to supplement the manned fighters. Since May 1958, ADC's squadrons have been under the operational control of NORAD. Cross border training between northern US based air defence squadrons and the RCAF interceptor squadrons continues, and USAF fighters are a familiar sight on RCAF bases as part of joint defence exercises. To support the CF-100s of today and the Bomarc of tomorrow, ADC continues to operate an extensive electronic ground environment. These chains of detection and control radars, coupled with a complex communication system, are continuously being improved in preparation for the semi-automatic ground environment or SAGE system that will become operational in the next few years.

The Auxiliary Force

During the Fiftieth Year, all RCAF auxiliary squadrons were re-equipped to perform the new military liaison and civil defence roles in which they have been recast. To carry out this new task, the squadrons are being equipped with Expeditor light transports and several squadrons will receive Otter aircraft in the future to increase their capability to meet their role. As part of the general reorganization, auxiliary units have been placed under the command headquarters nearest to their geographical location.

Miscellaneous activities

In addition to the Air Force's roles and activities already mentioned, a summary of RCAF undertakings in the Fiftieth Year would be incomplete without reference to the Search and Rescue and the Golden Hawks. During 1959, the Search and Rescue organizations of the Air Force continued to provide extensive service to the military and civilian aviators who were unfortunate enough to crash or otherwise be in distress. To all those who take to the skies for business or pleasure, the knowledge that a well organized search and rescue facility is always ready in the event of an emergency, gives passengers and crews a feeling of security.

In special recognition of the Fiftieth Anniversary of Powered Flight in Canada and also the Thirty-fifth anniversary of the RCAF, the Air Force formed the Golden Hawks Aerobatic Display team equipped with the famous Sabre aircraft. This team demonstrated their skills to millions of Canadian and Americans at shows from coast to coast and in the USA.

CONCLUSION

This paper has been a short summary of Canadian aviation in the Fiftieth Year. This year, as in the past, it can be seen that the aeroplane has made a major contribution to the development of Canada. Our nation has been fortunate indeed, in the last fifty years, to have had men of foresight and tenacity who have understood and developed the potential of the aeroplane. There is every indication that their successors in 1959 are upholding their fine tradition. The future of aviation in Canada is, as it has always been, a challenge.

LIQUID ROCKET PROPELLANTS†

by Dr. R. Sandri*

National Research Council

INTRODUCTION

THIS article deals primarily with liquid substances used for the propulsion of rockets by chemical action. Dependent on whether this action consists of the decomposition of a single substance or of reactions between oxidizer and fuel, we have to distinguish between monopropellants and bipropellants. (Mixtures of oxidizer and fuel might also be considered as monopropellants but they are not at present in use.)

It is first necessary to discuss the general characteristics of rocket propellants and their importance. After that, a brief survey will be made of some propellants frequently used at present as well as of some which show promise for the future.

PROPELLANT CHARACTERISTICS

In general, the best propellant, or propellant combination, will be that which produces the maximum thrust with the minimum propellant consumption. Measuring thrust in pounds and consumption in weight pounds per second, one obtains the parameter called specific impulse I_s in seconds. Therefore, a propellant combination with $I_s = 200$ sec produces a thrust of 200 lb for a fuel consumption of 1 lb/sec or we may say that 1 lb of the same propellants produces a thrust of 1 lb for a duration of 200 sec. Since the thrust is the force acting on the rocket on one hand and on the exhaust gases on the other, we obtain the velocity of the exhaust gases by multiplying the specific impulse by the acceleration due to gravity, i.e. 200 sec $\times$ 32.2 ft/sec^2 = 6440 ft/sec.

Unfortunately, substances rich in energy which produce high specific impulses usually produce high combustion temperatures also. Heat resistance of the rocket chamber sets a limit to temperature, particularly if the engine is to be used for a long time, e.g. in rocket aircraft. A relatively low combustion temperature for a given specific impulse can be expected if the molecular weight of the combustion products is low.

The specific impulse is, of course, not only dependent on the propellants but also on the design and operating conditions of the rocket engine. For a given propellant, or propellant combination, both specific impulse and combustion temperature increase with chamber pressure because pressure counteracts dissociation of the burned gases. In addition, high pressure allows the engine to be made smaller. On the other hand, mechanical and thermal stresses and propellant pump power consumption increase with pressure. A chamber pressure of 300 psia is most frequently used but values up to 900 psia have been recommended[1]. Another parameter affecting I_s is the expansion rate which, for supersonic nozzles, depends on the size of the nozzle exit area as compared with the throat area. The expansion rate is therefore limited by design considerations.

To give a basis for comparison, I_s is usually calculated for a chamber pressure of 300 psia and expansion to atmospheric pressure, i.e. expansion rate is approximately equal to 20. Moreover, "frozen equilibrium" is assumed. This means that recombination of dissociated molecules in the exhaust nozzle is disregarded. The actual values of I_s are somewhat lower than the theoretical values (2% to 15%, dependent on size and design of the engine used).

The specific gravity of the propellants is also very important. It should be high so that the propellant tanks can be comparatively small.

A high boiling point allows the propellant to be used for regenerative cooling of the combustion chamber and nozzle. High heat of vaporization and high heat capacity are desirable from the same point of view. Viscosity should not be too high, otherwise pump power consumption becomes excessive.

Some propellant combinations are "hypergolic" i.e. they ignite spontaneously when brought into contact so that no ignition system is required.

Other characteristics of the propellants affect their storage and handling. High boiling point and low freezing point are desirable. Obviously, chemical instability is very undesirable; next to that, corrosive effect on metals, reactivity with organic substances and toxicity of propellants and combustion products. Last but not least, the propellants should be readily available and cheap.

Keeping these conditions in mind, we can now proceed to consider some rocket propellants in particular.

Monopropellants

Liquid monopropellants, as compared with bipropellants, offer the advantage of simplicity of use and handling which increases reliability and readiness for use. Only one propellant tank, one pump and one valve system are

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*Associate Research Officer.

needed and no mixture ratio control is required. In spite of this, monopropellants have not been used often, owing to their lower specific impulse.

The following substances should be mentioned here: ethylene oxide, ethyl nitrate, hydrazine, nitromethane, n-propyl nitrate and hydrogen peroxide. Of these, nitromethane has the highest specific impulse (approximately 220 sec), while hydrogen peroxide has the lowest (126 sec). All these substances, however, are used to better advantage together with other substances, as bipropellants, where they yield higher specific impulses. Hydrogen peroxide is seldom used as a monopropellant but rather as an auxiliary substance. With permanganate solution as catalyst, it produces a mixture of hot steam and oxygen which can be used for driving propellant turbopump systems (e.g. in the German V-2 rocket).

The hope has been expressed that monopropellants of higher specific impulse (up to 240 sec) may be developed, possibly as mixtures of fuel and oxidizer. Such mixtures, if they could be safely stored and handled, would combine the advantages of monopropellants and bipropellants[2].

Bipropellants

Bipropellants comprise oxidizers and fuels. Inert substances like water may be added to improve stability, lower combustion temperature or counteract dissociation. A great many combinations are theoretically possible, of which only a few will be considered here. More data can be found in the References 3 and 4.

Table 1 contains some physical data for oxidizers and fuels. Only those substances have been listed here which are used in the combinations shown in Tables 2 and 3. Specific gravity and specific heat are given for room temperature, except for liquefied gases such as fluorine or oxygen where they are given for the boiling temperature. The remark "reactive" refers to reactivity with organic substances. The boiling intervals shown for gasoline and kerosene correspond to 10% to 90% evaporation. Hydrazine is often mixed with water (68% hydrazine) which lowers its freezing point to –63°F.

Table 2 shows data for some propellant combinations. Although the propellants listed here offer some difficulties in handling, storing, stability etc, these difficulties are not prohibitive and can be overcome by adequate precautions. Combustion temperatures are not excessive either, so that these combinations can be considered as "conventional". The specific impulses shown are theoretical values calculated for 300 psia and expansion to atmospheric pressure at sea level. They do not differ very much from an average value of 240 sec. An asterisk indicates that the combination is hypergolic.

In spite of its low boiling point, liquid oxygen is by far the most frequently used oxidizer for large rockets, especially in combination with alcohol or hydrocarbon fuels. Hypergolic combinations such as nitric acid and aniline or hydrogen peroxide and hydrazine are also popular. Each combination has its advantages and drawbacks; which is preferable depends chiefly upon the purpose for which the engine is to be used. For instance, high specific impulse will be less important for short-range than for long-range missiles; high cost of materials will be prohibitive for ordinary rockets but not for the upper stages of multi-stage rockets.

Recently a new fuel has been introduced which has about the same physical properties, storage and handling characteristics as alcohol so that it can be used in the same rocket engine without major changes and which gives a specific impulse about 12% higher than alcohol. It is "Hydyne" (UDETA), a 60/40% mixture of unsymmetric dimethyl-hydrazine ($NH_2 - N(CH_3)_2$) and diethylene-triamine ($(C_2H_4 - NH_2)_2NH$). It was used in the "Jupiter C" satellite rockets.

Naturally, attempts have been made, and will be made, to use combinations with higher specific impulse. A few high-energy propellant combinations which appear to be promising for the future are shown in Table 3.

Liquid hydrogen as fuel produces the highest specific impulses while the combustion temperatures are comparatively low. Unfortunately, due to its low density, it requires bulky tanks and its extremely low boiling point involves serious complications. Any contamination will freeze and clog the pipelines. Contamination with traces of air, for example, cannot be tolerated because the air would freeze and form an explosive substance. Storage vessels and propellant tanks become brittle and lose their impact resistance. Evaporation losses are high. In addition, gaseous hydrogen diffuses readily through metals, especially at high temperature. In spite of these difficulties, the advantage of the very high impulse is so great that it makes hydrogen a most interesting object of propellant research.

Borohydrides, which contain hydrogen in chemical combination, have attracted much attention. A serious disadvantage which seems to have prohibited their use as rocket fuels so far is the formation of solid deposits (boron oxides and boron). This tendency can be somewhat diminished by addition of a few per cent hydrocarbons or by alkylation. In experiments carried out with 95% diborane and liquid oxygen[6], $I_s = 249$ sec was measured. Correcting this value for heat losses (which in larger engines of suitable design can be substantially reduced) one finds $I_s = 274$ sec. The test engines used in these experiments were rather small (100 lb thrust, nominal). Pentaborane gives slightly lower specific impulses than diborane but is a liquid at room temperature (Table 1). Decarborane, $B_{10}H_{14}$ (melting point 211°F, boing point 415°F, specific gravity 0.94) has been considered as a high energy solid rocket fuel.

A considerable increase of I_s can also be obtained by the use of high energy oxidizers. Liquid fluorine gives higher impulses than liquid oxygen with the same fuels but the combustion temperatures are very high. Moreover, the low boiling point and high corrosiveness and toxicity render its handling extremely difficult. Nevertheless, the Bell Aircraft Corporation has recently succeeded in building a large liquid fluorine engine.

The high I_s values possible in combinations with liquid ozones as oxidizer, together with the higher density and relatively high boiling temperature of ozone, make this substance appear most attractive but its very high explosivity has so far prevented its use as a rocket propellant. Mixtures of liquid ozone and liquid oxygen are far

Table 1
Physical Properties of Liquid Propellants

Name	Formula	Freezing Pt. °F	Boiling Pt. °F	Specific Gravity	Vapor. Heat Btu/lb	Specific Heat Btu/lb °F	Remarks
(A) Oxidizers							
Fluorine	F_2	−361	−306	1.55	74	0.36	Very toxic, highly reactive, fire hazard
Hydrogen Peroxide (87%)	H_2O_2	6	282	1.38	602	0.62	Fire and explosion hazards
Nitric Acid, White Fuming	HNO_3	− 60	191	1.55	207	0.42	Highly corrosive, fire hazard, toxic
Nitrogen Tetroxide	N_2O_4	12	70	1.49	168	0.36	Very toxic
Oxygen	O_2	−363	−297	1.14	91.6	0.394	Highly reactive
Ozone	O_3	−314	−170	1.57	136	0.45	Very toxic, highly reactive, highly unstable, explosion hazard
(B) Fuels							
Ammonia	NH_3	−108	− 28	0.68	587	1.08	Toxic
Aniline	$C_6H_5NH_2$	20	364	1.02	187	0.48	Skin poison
Diborane	B_2H_6	−265	−134	0.43	202		Toxic, slag formation, fire hazard
Ethyl Alcohol (95%)	C_2H_5OH	−179	173	0.79	367	0.62	Fire hazard
Gasoline, Aviation		− 76 and lower	147–245	0.72	120–130 approx.	0.53	Fire hazard
Hydrogen	H_2	−434.5	−423	0.07	196	2.33	
Hydrazine	N_2H_4	35	236	1.01		0.75	Fire hazard
Kerosene, Aviation		− 55 and lower	340–470	0.81	113	0.49	
Methane	CH_4	−297	−259	0.41	248		Fire hazard, asphyxiant
Methyl Alcohol	CH_3OH	−144	148	0.79	474	0.59	Fire hazard
Nitromethane	CH_3NO_2	− 19	214	1.13	242	0.41	Explosive when heated
Pentaborane	B_5H_9	− 52	140	0.61			Toxic, slag formation, fire hazard

Table 2
Conventional Propellant Combinations

Oxidizer	Fuel	Oxidizer/Fuel Ratio	Specific Impulse Sec.	Combustion Temperature °F	Bulk Specific Gravity
Oxygen	Ammonia	1.25	250	4834	0.86
	Hydrazine	0.83	263	5382	1.07
	68% Hydrazine	1.00	242	4572	1.07
	Methane	2.33	263	4874	0.75
	Methyl Alcohol	1.15	237	5076	0.94
	95% Ethyl Alcohol	1.50	242	5297	0.97
	75%Ethyl Alcohol	1.31	234	4887	0.98
	Gasoline	2.26	252	5660	0.96
	Kerosene	2.28	249	5702	1.02
Nitric Acid, White Fuming	Hydrazine*	1.22	246	4681	1.23
	Aniline*	3.00	222	4942	1.36
	Methyl Alcohol	2.36	219	4480	1.19
	Gasoline	4.60	223	4941	1.25
87% Hydrogen Peroxide	Hydrazine*	1.69	240	4200	1.22
	Nitromethane	0.42	232	4719	1.20
Nitrogen Tetroxide	Ammonia	2.03	238	4627	1.06
	Aniline*	3.87	221	5742	1.34
	Hydrazine*	1.00	249	4905	1.19

*Hypergolic combination

Table 3
High Energy Propellant Combinations

Oxidizer	Fuel	Oxidizer/Fuel Ratio	Specific Impulse Sec.	Combustion Temperature °F	Bulk Specific Gravity
Oxygen	Hydrogen	2.89	345	3886	0.23
	Diborane*	1.74	300	6290	0.71
Ozone	Ammonia	1.13	267	5175	1.13
	Hydrazine	0.63	277	5418	1.20
	Hydrogen	2.65	373	4280	0.23
Fluorine	Ammonia*	2.90	296	7512	1.02
	Hydrazine*	1.98	300	7692	1.31
	Methyl Alcohol	2.37	298	7472	0.99
	Hydrogen	9.42	371	8072	0.46
	Hydrogen	3.77	356	4469	0.27
	Diborane	5.25	299	8540	1.10
	Diborane	3.16	287	6720	0.96
Hydrogen Peroxide	Diborane	1.90	286	5144	0.80

*Hypergolic combination

less dangerous than pure ozone and still offer an appreciable gain in I_s. Perhaps the future will bring developments in this direction.

High-energy propellant combinations would be most welcome in the upper stages of multi-stage rockets. On the other hand, high reliability is a prime consideration here so that these combinations will be useful only when adequate engines for their use are sufficiently well developed and tried out. By using higher chamber pressure, I_s can be made still higher. However, 400 sec seems to be about the limit for ordinary chemical propellants and higher specific impulses can only be obtained from other energy sources. A few words should therefore be said about these.

Free Radicals, Nuclear Energy and Ionic Propulsion

Free radicals, which can be regarded as a sort of chemical propellant, could yield much higher specific impulses than ordinary chemicals. Atomic hydrogen, for example, produces a specific impulse near 2000 sec, theoretically. Considerable progress has been made recently in the production of free radicals. They are produced electrically and cooled to a temperature near absolute zero. So far OH, N, O and H have been produced in frozen form. However, in order to store them at this low temperature, large amounts of coolant are needed so that the over-all specific impulse is considerably smaller than the theoretical value. Moreover, very high chamber temperatures would be needed. Therefore, at the present state of the art, it is not possible to use free radicals as propellants.

The idea of utilizing nuclear energy for the propulsion of rockets is obvious. The energy release per unit weight of uranium is exceedingly high, but the problem is how to convert a substantial portion of it into kinetic energy of the exhaust gases without attaining excessive chamber temperatures. It is necessary to transfer the heat developed in the atomic pile to a substance of low atomic weight which is then ejected through the nozzle. From a technological point of view, a nuclear rocket engine is therefore similar to an "external combustion engine" whose performance is dependent chiefly on the efficiency of heat transfer, whereas a chemical rocket engine is an "internal combustion engine".

The substance with the smallest molecular weight, and consequently the best propellant for nuclear rockets, is hydrogen. The maximum gas temperature is not likely to be above 2600°K (4200°F) because the reactor has to be considerably hotter than the gas to ensure satisfactory heat transfer. This corresponds to a specific impulse of the order of 700 sec[7]. The advantage of the high specific impulse, however, is more or less offset by the heavy weight of the nuclear powerplant and the complexity of the system. In addition, for manned vehicles, heavy shielding would be required so that the acceleration imparted to the rocket could only be a fraction of the gravity acceleration. For these reasons it appears that, at the present state of the art, manned nuclear rockets could only be used as upper stages of multi-stage vehicles operating at higher than orbital velocities. The velocity and range of such rockets would be limited only by the quantity of propellant medium that could be carried since energy is practically unlimited.

In rockets with ionic propulsion, specific impulses could be even higher because the ions of the exhaust gases are accelerated in parallel directions and prevented from hitting the wall of the nozzle by the electromagnetic field, so that temperature is limited by heat radiation only. In spite of this, the absolute thrust would be far smaller than in nuclear rockets because of the extremely small mass flow even for very high currents. Very high amounts of electric energy would be needed.

Of course, a major breakthrough in any of the fields mentioned could change conditions completely. Barring this, it seems reasonable to expect that only chemical propellants will be of practical interest until very large rockets capable of attaining higher than orbital speeds can be built.

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TECHNICAL FORUM

Aids to the Design of Pneumatic Servo Valves

BY J. D. MACNAUGHTON

Garrett Manufacturing Limited

INTRODUCTION

In the design of pneumatic servo valves, the dynamic and steady state characteristics of orifice and volume systems play an important part.

A deterrent to the study of these systems during the preliminary design stages is the relatively large amount of engineering time which must be spent to solve the classical equations governing orifice calculations. This might involve numerical solutions to differential equations and/or analogue computing studies.

The following describes a mathematically tractable solution to orifice calculations which the author has found to reduce preliminary design calculation time to a minimum and to be sufficiently accurate for these purposes.

LIST OF SYMBOLS

- W Weight flow – lb/min.
- θ Dimensionless temperature – absolute temp/519°R.
- C Orifice discharge coefficient.
- A Orifice area – in².
- δ Dimensionless pressure – absolute press/14.7 psia.
- r Pressure ratio.
- p Total pressure – psia.
- V Volume – in³.
- T Total temperature – °R.
- m Mass – lb.
- R Gas constant – 641 in/°R for air.
- t Time – min.
- γ Ratio of specific heats – C_p/C_v.
- P Integration constant

Subscripts

- o Denotes upstream.
- 1 Denotes downstream.

BASIS OF SIMPLIFYING ASSUMPTION

The basic problem facing the designer is that most orifices operate under two flow regimes, i.e. pressure ratio across orifice less than critical (0.528 for air) resulting in choked flow, and pressure ratio across orifice greater than critical resulting in unchoked flow. Thus, a discontinuity in the mathematical expressions governing orifice flow occur at the critical pressure ratio, thus making computation time consuming. The isentropic relation governing air flow through a choked orifice is

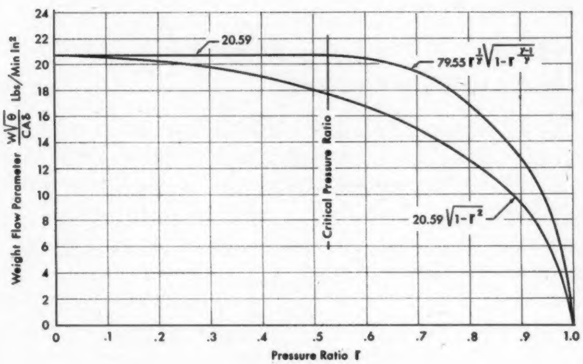


Figure 1
Comparison between isentropic and empirical relationships

$$\frac{W\sqrt{\theta}}{CA\ \delta} = 20.59 \tag{1}$$

The isentropic relation governing air flow through an unchoked orifice is

$$\frac{W\sqrt{\theta}}{CA\ \delta} = 79.55\, r^{\frac{1}{\gamma}} \sqrt{1 - r^{\frac{\gamma - 1}{\gamma}}} \tag{2}$$

Eqs. (1) and (2) are plotted in Figure 1.

A search for an empirical mathematical expression combining both flow regimes was undertaken and resulted in the following formula;

$$\frac{W\sqrt{\theta}}{CA\ \delta} = 20.59 \sqrt{1 - r^2} \tag{3}$$

Eq. (3) is also plotted in Figure 1 and may be compared with the isentropic result. A direct comparison would indicate that the error associated with the assumed law could be quite large unless the range of pressure ratios considered is also large.

However, the isentropic relation does not represent the physical phenomena for the following reasons;

†Received 5th October, 1959.

(a) The flow is not isentropic.

(b) High Mach number effects in the orifice throat modify the orifice discharge coefficient in a region either side of the critical pressure ratio.

(c) Orifice discharge coefficient in the subsonic regime is not independent of orifice pressure ratio.

As a result, these deviations modify the isentropic curve in the direction of the assumed curve. This has been borne out by testing of small orifices, the results being in satisfactory agreement with the assumed equation.

EXAMPLES OF METHOD

The following details the solution to several common orifice problems encountered in servo valve design. The basic assumptions used in the analysis are:

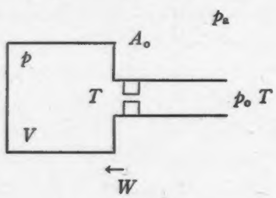
(a) Isothermal process.

(b) Perfect gas law applies.

(c) Zero pressure recovery downstream of orifice(s).

(d) Air is the fluid medium.

(i) Charging a constant volume chamber through an orifice from a constant pressure source. Problem — to express chamber pressure as a function of time.



The perfect gas law states

$$\frac{pV}{m} = RT$$

or

$$m = \frac{pV}{RT} \tag{4}$$

then

$$\frac{dm}{dt} = W = \frac{V}{RT}\frac{dp}{dt} \tag{5}$$

but from Eq. (3)

$$W = \frac{31.9\ CA_o p_o}{\sqrt{T}}\sqrt{1 - \left(\frac{p}{p_o}\right)^2} \tag{6}$$

Combining and rearranging Eqs. (4) and (6), we have

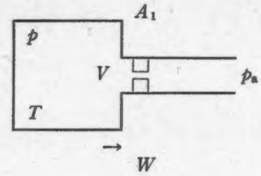
$$dt = \frac{V}{31.9\ CA_o R\ \sqrt{T}}\ \frac{dp}{\sqrt{p_o^2 - p^2}} \tag{7}$$

Integration of Eq. (7) yields

$$t = \frac{V}{31.9\ CA_o R\ \sqrt{T}}\left[\sin^{-1}\frac{p}{p_o} - \sin^{-1}\frac{p_a}{p_o}\right] \tag{8}$$

with the initial conditions that $p = p_a$ when $t = 0$.

(ii) Discharging a constant volume chamber through an orifice. Problem — to express chamber pressure as a function of time.



As in Eq. (5) we have

$$\frac{dm}{dt} = W = -\frac{V}{RT}\frac{dp}{dt} \tag{9}$$

and from Eq. (3)

$$W = \frac{31.9\ CA_1 p}{\sqrt{T}}\sqrt{1 - \left(\frac{p_a}{p}\right)^2} \tag{10}$$

Combining and rearranging Eqs. (9) and (10) we have

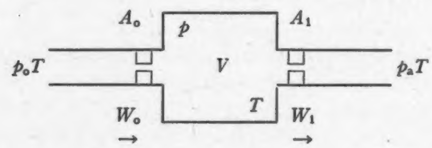
$$dt = \frac{V}{31.9\ CA_1 R\ \sqrt{T}}\ \frac{dp}{\sqrt{p^2 - p_a^2}} \tag{11}$$

Integration of Eq. (11) yields

$$t = \frac{V}{31.9\ CA_1 R\ \sqrt{T}}\log_e\left[\frac{p_o + (p_o^2 - p_a^2)^{\frac{1}{2}}}{p + (p - p_a^2)^{\frac{1}{2}}}\right] \tag{12}$$

with the initial conditions that $p = p_o$ when $t = 0$.

(iii) Steady state pressures in a chamber whose inlet and outlet ports are controlled by fixed orifices.



Flow through A_o is given by

$$W_o = \frac{31.9\ CA_o p_o}{\sqrt{T}}\sqrt{1 - \left(\frac{p}{p_o}\right)^2} \tag{13}$$

Flow through A_1 is given by

$$W_1 = \frac{31.9\ CA_1 p}{\sqrt{T}}\sqrt{1 - \left(\frac{p_a}{p}\right)^2} \tag{14}$$

In the steady state

$$W_o = W_1$$

$$\therefore \frac{A_o}{A_1} = \sqrt{\frac{p^2 - p_a^2}{p_o^2 - p^2}} = \sqrt{\frac{1 - r_1^2}{\frac{1}{r_o^2} - 1}} \tag{15}$$

CONCLUSION

The above methods may be used for the solution of many more orifice problems, both steady state and transient, such as those involving adiabatic or polytropic processes, time variant volumes or orifices, etc.

Some Aspects of
Future Air Transport Possibilities

On reading Sir George Gardner's paper "Some Aspects of Future Air Transport Possibilities", I was somewhat intrigued by the apparent discontinuity in the number of aircraft required vs flight time for a 24 flights per day service between London and New York. Doubtless, assumptions or requirements additional to those mentioned in the paper must have intervened because if one adheres strictly to the following requirements:

(a) no departures or arrivals between 0 hr and 6 hr, local time,

(b) minimum spacing of departures, 15 minutes,

(c) at least 3 hr stop-over at London, 2 hr at New York, and

(d) 24 round trips per day.

then it is possible to schedule:

24 aircraft with a 7 hr flight time
18 aircraft with a 5 hr flight time
13 aircraft with a 3½ hr flight time
14 aircraft with a 2½ hr flight time

The above numbers do not include spare or grounded aircraft. Figure 1 shows how these schedules might be arranged. It is interesting to note, first, that a reduction in flight time from 7 to 5 hrs allows a substantial reduction in fleet size. Second, that improved utilizations result from relaxing the 24 flights/day requirement for all flight times other than 7 hrs (e.g. 23 trips/day with 17 a/c and 5 hr flight time, 22 trips/day with 11 a/c and 3½ hr flight time, etc).

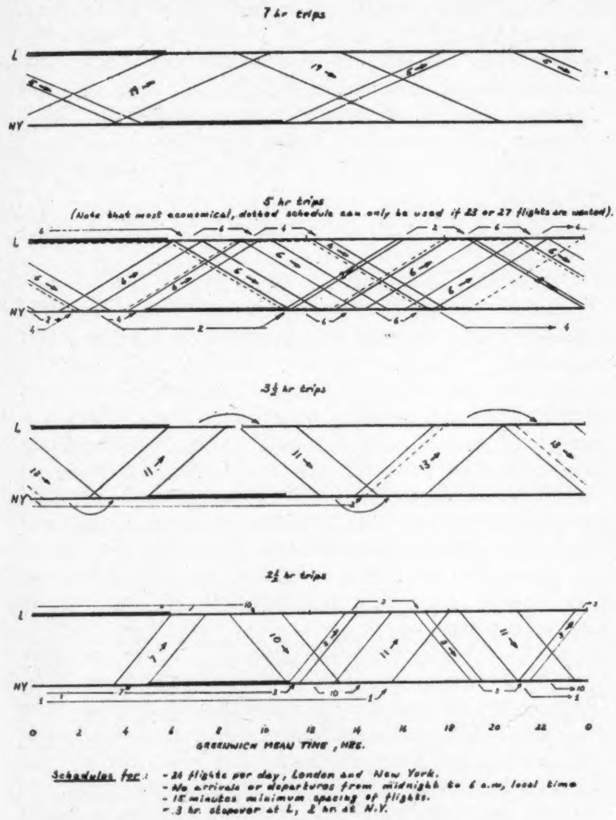


Figure 1

Longueuil J. C. Vrana

Sir George Gardner has replied:

I agree with Mr. Vrana's comments, which show that if one accepts a rather complicated timetable it is possible, under the assumptions stated, to reduce the size of fleet cruising at $M = 1.2$. The reason I introduced these timetables was to make the point that for a particular route there are speeds above which significant reductions can be made in the size of fleet to cope with a given load. In considering a network of routes the discontinuities will be able to squeeze in an extra trip here and there, but I believe that some operational research in this field may pay handsome dividends.

London G. W. D. Gardner

MID-SEASON MEETING

KINGSWAY MOTOR HOTEL
EDMONTON

19th and 20th February, 1960

19th February

Morning	9.00 a.m.	Fuels and Oils
Afternoon	2.00 p.m.	Astronautics
Evening	8.30 p.m.	Electronics (Tutorial)

20th February

Morning	9.00 a.m.	Operations
Afternoon	2.00 p.m.	Propulsion
Evening	7.00 p.m.	Dinner

LETTERS TO THE SECRETARY

MAN-POWERED FLIGHT SECTION

I HAVE read with interest your suggestion (page 303 of the September, 1959, issue) that a Manned Flight Section of the CAI should be formed. I think this is a very good idea, however it might prove more worthwhile to found a Section devoted quite generally to low speed flight. Such a Section would review and possibly coordinate activity, particularly that devoted to research and development, in the following fields:

(i) Natural flight, including that of insects and birds.

(ii) Lighter-than-air craft.

(iii) Rotor wing aircraft, including helicopters and autogyros.

(iv) Ground cushion vehicles.

(v) Conventional low-speed aircraft including VTOL and STOL types.

(vi) Gliders and man-powered craft.

I am very interested in your proposal and wish to support any activity in this field. I think a Low Speed Flight Section would be both useful and stimulating in a field of aeronautics which is of real interest to Canada.

Montreal — B. G. NEWMAN

HELICOPTER SECTION

I HAVE just got around to reading the September issue of the Journal, in which you asked for comment on the possibility of forming a Helicopter Section. If such a Section is formed, I shall certainly join it. However, I am not entirely clear on the advantages of having separate Sections – eventually there will be nothing left for the non-specialist. Also, if helicopter papers are given at general meetings some fixed-wing people may hear them and learn something. They will not attend sessions of a Helicopter Section.

There is a question whether there is sufficient helicopter activity in Canada to justify a Section. There is a danger that it might take the form of a Mutual Condolence Society for frustrated helicopter engineers, like myself. Perhaps the operational side of the business could keep things going until the situation improves. Insufficient activity can lead to atrophy.

You are correct, the true helicopter man would rather not have VTOL included; however, few of us are pure. Most of the VTOL work has been done by helicopter people, since the technology is similar, and hence it has become the practice for VTOL work to be included within the scope of the helicopter associations. There seems to be no reason to deviate from this.

I shall be interested to hear of any further developments.

Montreal — G. N. ADAMS

(If I may comment on these letters, I think that Professor Newman's suggestion is too broad and Dr. Adams' preference for the exclusion of VTOL is too narrow.

It can be argued that Professor Newman's Low Speed Flight Section would be no broader than the Astronautics Section. I agree; personally I think that the Astronautics Section is too broad – or will be as the field develops and tends to fall into natural subdivisions. Low speed flight already has developed to such a stage and each subdivision has its specialists. Their common ground is provided in the broader relationship of the Institute itself rather than in a Section with a low level of specialization.

This to some extent answers Dr. Adams' question about the advantages of having separate Sections. The Sections are supposed to be quite narrow, to treat their respective subjects as deeply as they can go, and to guide the Institute and the Branches in their treatment of these subjects in Institute and Branch activities (meetings, the Journal, etc). Moreover, Section meetings are open to all members of the Institute; if any non-specialist is sufficiently interested to seek a deeper penetration of any particular subject than he gets at Institute or Branch meetings, he is free to attend Section meetings and get all the flute music he wants.

Let us have some more letters. There is the making of a discussion here. – Secretary).

C.A.I. LOG

SECRETARY'S LETTER

THE BRANCHES

In the last issue we began a series of reports on the Branches, which will run through, I hope, until March. The Publications Committee thought that such a series would be interesting, giving a general review of the nature and activities of each Branch in turn, outlining its special problems and needs, and passing on ideas which might be usefully adopted by the others. These reports are being written by the Chairmen of the Branches and we are grateful to them for this additional contribution to the life of the Institute.

In this connection I should like to say a word for the Branch Chairmen. We are all inclined to assume that Branch activities just happen or, at least, that the Branch Executive Committees will see to it that they do. But we rarely appreciate how difficult it is for a Committee to work effectively – the Secretary lives here, the Treasurer lives twelve miles away from him, the Chairman travels a lot and so on; it all devolves upon the Chairman to get these scattered people together periodically, to give them jobs to do and to see that they do them. If he doesn't, the life of the Branch just stops.

The bulk of the Institute's work is done in the Branches and I doubt whether the responsibility carried by these nine Chairmen is properly appreciated by all of us who benefit from it.

PAPERS BY MEMBERS

They tell me that people read the Secretary's Letter. If this is any more than flattery I should like to take advantage of it and draw attention to the fine print in the notice about the Annual General Meeting appearing on page 404. The primary purpose of this notice, months before the event, is to give members an idea of the programme and to invite them to submit papers for consideration.

It is important that we should develop the habit of presenting papers. In Great Britain and the USA people have developed the habit as part of their professional life and their employers foster and encourage it; but in Canada the idea has not yet caught on. We are still inclined to think that we go to meetings to learn something by listening. We must realize that we cannot take a full part in our profession unless we are prepared to talk; we shall learn something just the same, from the very process of putting our thoughts in order to prepare our papers, and from the comments and questions that the papers evoke.

The submission of papers for presentation at Branch or Institute meetings is always welcome and the papers will be fitted in whenever the programme permits – and it usually does. In the case of Institute meetings, though it will probably always be necessary to choose some of the sessions to give some direction to the over-all programme, I am sure that others could be arranged to accommodate papers known beforehand to be available. In the absence of such papers the Programmes Committee must choose all the sessions first and then try to find papers appropriate to them; and the first step in this search, particularly for the Annual General Meeting, is to invite papers from members. Let us have a good response this time.

CHRISTMAS 1959

Well, 1959 has been quite a year. We have duly celebrated the Golden Anniversary of Flight in Canada. In company with our fellow Canadian engineers, we have entertained our Patron, the Prince Philip, at a memorable luncheon. We have taken part for the first time in the Anglo-American Conference. And, on the other side of the coin, we have suffered the bitter disappointment of the cancellation of the Arrow and the Iroquois, and all the disruption that followed. The staff joins me in wishing all our members a Happy Christmas and a New Year as eventful, if not as revolutionary, as the last.

BRANCHES

SURVEY OF THE BRANCHES

Montreal

By R. F. O. Smith
Chairman

The Montreal Branch is fortunate in being located in an area which contains elements comprising a broad cross-section of the aviation industry, including government agencies; scheduled airlines; charter operators; flying clubs; sales and service organizations; and engineering and production of aircraft and components, electronic equipment and missiles. In all, there are represented on our roster 46 companies, the RCAF, ICAO, IATA and the Department of Transport, as well as five Universities and Colleges. The Branch was formed in 1954 and was provided with a fund of experience and organizational ability from the membership of the Institute of Aircraft Technicians, which, it will be remembered, dissolved itself and handed over its assets to the Institute. It is noteworthy that many of the stalwarts of the IAT have continued from time to time as active members of the Executive and Operating Committees of the Montreal Branch.

Nominating Committees sometimes have a difficult task in proposing an Executive which is truly representative of the activities in the area and, by the same token, the Executive must be careful to appoint Chairmen of Operating Committees from as many of the activities as possible. Over the years a reasonable balance has been struck; nevertheless this consideration must be kept constantly in mind.

Active liaison is maintained with specialist Sections of the Institute and joint Branch-Section meetings are scheduled with the Astronautics, Propulsion and Test Pilots Sections. It has become customary to hold a joint meeting with the Montreal Chapter of the SAE; this event usually occurring in April when a topic of mutual interest is presented before a large audience. Technical meetings are held each month from September through April except in December when a social evening is enjoyed by members and their ladies. Meetings are usually held in the Airlines Cafeteria of the International Aviation Building and are preceded by an informal 'get-together' session over a glass or two of beverage and a dinner. A notable annual event is the Golf Tournament in August, which has become an occasion eagerly anticipated by members from far and wide. Three very handsome trophies are competed for each year; the Ev. Shaefer Memorial Trophy for competition by all members of the CAI, the Bob Wright Memorial Trophy for competition by members of the Montreal Branch and the Harold Ross Trophy for competition by guests. Mr. J. Chadborn, who has become closely identified with the tournament over the years, usually manages to come by sufficient prizes, valuable and otherwise, to keep everyone happy, including the duffers.

The Students Section is intended to cater to students from McGill, Sir George Williams, Loyola, Ecole Polytechnique and College Militaire Royale de Saint-Jean. There have been active programmes at the first two for over a year and negotiations for student activities at the latter three are under way. The Branch provides the Students Section with speakers and films and also arranges plant tours. A Student Essay Competition is sponsored by the Branch and all students of the aforementioned colleges are eligible whether members or not.

The Branch membership is now 550, and it is encouraging to note that 14 new members have joined during the 1959-1960 season. The usual problems of tracking down members at the start of a new season are much in evidence, and some method of keeping in touch during the summer months seems to be desirable. A system of recording attendance at Branch meetings has been initiated and it is hoped eventually by this means to discover what combination of venue, date, subject, etc, would result in maximum attendance. Average attendance at technical meetings is about 15% of membership, which at first sight appears low. However, when allowance is made for out of town assignments, pressure of business and conflicting activities, and in comparison with attendance at meetings of other organizations, this percentage is not too far from that to be expected in this area.

From time to time the Branch has been called upon to organize or assist in arrangements for Annual CAI Meetings, Joint IAS/CAI Meetings and the 50th Anniversary Meeting. These occasions, though they involve a lot of work, offer an opportunity for direct contributions to the Institute's programme, as distinct from Branch activities, and the necessary close liaison between Headquarters and the Branch is a pleasant experience for all concerned.

Montreal Branch Executive Committee
(l to r): Mr. F. C. Phillips, Mr. E. H. Higgins, Mr. W. H. S. Bird, Mr. R. F. O. Smith and Mr. H. H. Whiteman.
Inset: (l) Mr. D. Boyd and (r) Mr. C. M. Newhall

Halifax-Dartmouth

By R. Wallworth
Chairman

The Halifax-Dartmouth Branch of the Canadian Aeronautical Institute was formed in November 1956 after prodigious efforts by Mr. E. C. Garrard and CPO R. L. S. Sabourin. At that time there were 12 members and 22 applicants. The inaugural meeting of the Branch was held in the Chief Petty Officers' Mess at HMCS Shearwater on

Halifax-Dartmouth Branch Executive Committee
Standing (l to r): CPO R. L. S. Sabourin, Mr. E. C. Garrard, Mr. H. J. Comeau, L/CDR G. Cummings, Mr. W. G. Stewart and CDR E. B. Morris.
Sitting (l to r): F/L D. Cooke*, Mr. R. Wallworth and Mr. J. Cornelius.
***F/L Cooke, on transfer, has been replaced by Lt J. A. Turner as Secretary.**

the 9th January, 1957, under the Chairmanship of Mr. Garrard, at which 45 members and guests heard the aims and objects of the Institute read, and elected interim officers in the persons of: Mr. E. C. Garrard, Chairman; CPO R. L. S. Sabourin, Vice-Chairman; Professor O. Cochkanoff, Secretary-Treasurer; Mr. J. L. Smale, Chairman of Nomination and Membership Committee; and CDR E. B. Morris, Chairman of Programme Committee. Mr. Garrard read our first paper with the appropriate title of "The Beginning of the Design of an Aircraft".

In April of that year we held our first properly constituted Annual General Meeting at which 38 members and guests were present who heard our Interim Treasurer announce that the Branch could now boast of 30 fully paid up members. At this meeting the results of the card ballot for election of Officers was announced and the following members were inducted: Chairman, Mr. E. C. Garrard; Vice-Chairman, CPO Sabourin; Treasurer, F/L E. C. MacInnis; Secretary, Mr. H. S. MacCaskill; Councillors, CDR E. B. Morris and L/CDR J. C. Sloan.

At this first Annual Meeting we had some very distinguished guests, notably Mr. H. C. Luttman, the Secretary of the Institute, who gave us a very informative and instructive talk on the activities and ambitions of the Institute and expressed pleasure that the formation of the Halifax-Dartmouth Branch now completed a chain that extended from coast to coast.

The second Annual Meeting showed that we had grown in membership from 30 to 45 and our first year of trial operation was over.

A new slate of Officers was elected as follows: Chairman, CPO R. L. S. Sabourin; Vice-Chairman, Mr. R. Wallworth; Secretary, Lt J. A. Turner; Treasurer, Lt N. B. Davis; Councillor, Mr. E. C. Garrard; Chairman of Membership Committee, CPO A. C. Green.

Again we had the pleasure of having Mr. H. C. Luttman with us and profited from his sage advice. We held nine ordinary meetings during the year with an average attendance of 34 and one extraordinary meeting which attracted 80 members and guests.

During the year we had been privileged to hear authorities talk on a wide range of subjects, including the design of hydrofoils; aviation fuels and lubricants; corrosion of metals; the effect of acceleration on the human frame; aerodynamics of everyday things; servo mechanism; and the highlight of the year when we had a Presidential visit from Group Captain H. R. Foottit at a meeting on 29th October, 1957. Such was the magnetism of the President that rather more than 80 members and guests listened to his learned paper on "The Technical Development of Air Power".

At the third Annual Meeting held on 15th April, 1959, it was reported by the Treasurer that the Branch now had 58 members in good standing.

Officers elected for the current year are: Chairman, Mr. R. Wallworth; Vice-Chairman, L/CDR G. Cummings, RCN; Secretary, Lt J. A. Turner, RCN; Treasurer, Mr. J. Cornelius; Councillors, Mr. E. C. Garrard, CDR E. B. Morris, RCN; Chairman, Program Committee, Mr. W. G. Stewart; Chairman, Membership & Nominations Committee, Mr. H. J. Comeau; Chairman, Publicity Committee, Mr. J. Milman.

There had been nine ordinary meetings during the year with an average attendance of 28. During the year interesting papers were read on various subjects connected with the production and use of aircraft and including weather aids to aviation, the toxic effect of aircraft fuels on humans, survival in the bush, hydrofoil theory and analog computors by authorities on the various subjects. Probably the greatest single event of this year was the 50th Anniversary Dinner which took place at the Nova Scotia Hotel on 23rd February, 1959. The head table was graced by a representative cross section of the social, Service and political society of Nova Scotia headed by the Premier of the Province and the Heads of the Maritime Commands of the three Fighting Services. This event really marked something of an epoch in the history of the Institute in this Province. A Committee consisting of the Vice-Chairman and Mr. R. Wallworth was set up to arrange a celebration of this day. It was thought that the single influence of the Halifax-Dartmouth Branch of the CAI was not sufficient to ensure the success this project demanded. Accordingly since essentially 'Flight' is an engineering problem the two senior engineering organizations, the Engineering Institute of Canada and the Association of Professional Engineers of Nova Scotia were consulted. As a result a Committee was formed under the Chairmanship of Mr. R. Wallworth and consisting of CPO Sabourin (CAI), Mr. C. E. Marshall (EIC), Mr. O. Nelson Mann (APENS), Mr. D. Wallace of the Department of Trade and Industry, with CDR E. B. Morris attending as representative of the National Committee to organize the celebration.

It should be noted that except for Fairey Aviation & Cossors on the Industrial Front and HMCS Shearwater on the Service Front there is little activity in the aircraft field and the EIC and the APENS were hardly aware of the existence of the Canadian Aeronautical Institute. This combined effort enabled us to exhibit to our engineering colleagues that we were, in fact, a very lively and virile organization and the culmination is that we have instituted what will be an Annual Joint Meeting of the three organizations.

Little known photographs of the persons and the first machines were borrowed from Mr. Bedwin whose father was the superintendent of Dr. Bell's workshop, together with the wonderful collection of model aircraft belonging to the Fairey Aviation Company of Canada and aerial photographs of the Halifax-Dartmouth area supplied by Atlantic Aviation were on display and were the subject of much appreciative comment during the cocktail hour which preceded the dinner.

More than 200 members and friends attended the function and joined with

Mr. D. O. Turnbull, whose famous father was a close collaborator of Dr. Bell and his Aerial Experiment Association, in paying homage to the pioneers of the aeronautical age.

The Branch had the honour of being hosts to the Annual General Meeting of the Institute in June of this year and many of our rank and file members took advantage of the opportunity of attending the meeting and seeing and hearing the learned ones of the aeronautical world discourse upon their activities.

We are fortunate too in that we have had the active co-operation of the personnel at the Naval Research Establishment and of the Nova Scotia Technical College in meeting the great demand for authoritative voices to tell us of the technical advances made and hoped for. The Services too have been a tower of strength to us in this field.

NEWS

Cold Lake

Change of Branch Officers

Vice-Chairman – S/L R. E. Zwicker has replaced F/L L. F. Bolger.

Treasurer – WO1 G. A. Feltmate has replaced FS T. R. Drinkwater.

Reported by J. B. Panton

September Meeting

The Branch held its first meeting of the current season in the Ground Instructional School Theatre on the 23rd September when the station was on a Security alert. This naturally restricted the attendance. The Branch Chairman, Mr. J. B. Panton, presided over the meeting and, before introducing the speaker, F/L J. A. Tarzwell of the CEPE Data Section, he gave a brief outline of the aims and ideals of the CAI to the 28 members and guests present.

F/L Tarzwell then gave an interesting and informative talk on Missile Navigation Systems. It was soon apparent that a great deal of work was necessary to prepare for the talk as evidenced by the many charts and graphs that were used throughout the lecture. The speaker clearly indicated his knowledge of a difficult subject as he traced the development and refinements of five types of navigation systems and noted the pros and cons of each system as used in various types of missile. A lively discussion period following the lecture indicated the interest the speaker had aroused in his listeners on a very timely and current topic.

Mr. C. B. Jeffrey thanked the speaker and noted that it was the first time he had been able to grasp some of the involved processes that are required in the refined armament missiles of this modern age.

October Meeting

The October meeting of the Branch was held in the GIS Theatre on the 26th of October. Mr. J. B. Panton, the Branch Chairman, introduced the speaker, Mr. C. B. Jeffrey of Computing Devices of Canada, who gave an interesting talk on notes taken at the Institute of Aerophysics, Aero Space Conference, held at the University of Toronto.

Dealing briefly with some of the papers given at the conference the speaker then enlarged on the design of the new supersonic wind tunnel now being constructed at the National Aeronautical Establishment in Ottawa. He then mentioned the studies of missile aerodynamics being done at the Canadian Armament Research and Development Establishment at Valcartier, Quebec. Mr. Jeffrey concluded his talk with the questions and answers raised at a panel discussion at the conference dealing with the subject, "Does Canada have a role in the Space Age?" It was thought that much useful information and study could be done by Canada. At the conclusion of the talk, the speaker was thanked by S/L A. E. Kelly.

Following a short break two films were shown. "An introduction to Survival" and "H Hour Now". The later picture dealt with the safety measures and preparation necessary to protect an Air Force station from the effects of fall-out, should a nuclear bomb be exploded near the base.

Refreshments were then served and a general discussion took place on many and varied subjects.

Winnipeg

Reported by G. P. Gulland

October Meeting

A dinner meeting was held on the 27th October at the Winnipeg Flying Club. The Branch Chairman, Mr. B. W. Torell, was in the chair. Mr. T. Baker introduced the speaker of the evening, Mr. D. G. Barber, Petroleum Engineer, Imperial Oil, Winnipeg. Mr. Barber's topic was "Refining Oil for Aviation Use".

The speaker introduced his talk with the showing of a film entitled "What makes Gasoline Good". The film used the Disney "animated cartoon" approach to illustrate the various formations of hydrocarbons in gasoline and the use of additives. Following the film, Mr. Barber briefly covered the refining of crude oil. Firstly, by atmospheric distillation and, secondly, re-distillation by the cracking operation. He used two schematic mock-ups to show these processes. The cause of gum formation, the corrosive effect of sulphur, detonation and the means Imperial employs to control these harmful effects were explained.

The talk was designed to satisfy moderately technical people and generated a tremendous interest among the members who questioned Mr. Barber for nearly 40 minutes. The questions ranged from "What is the difference between Motor Method and the Research Method of determining Octane Rating?", "What is the difference between Octane Rating and Performance Number?" to "What is Luminosity and how is it determined?"

At the conclusion of the talk, Mr. D. Newey thanked the speaker for a very interesting evening and the meeting was adjourned.

Vancouver

Reported by J. W. Whiskin

October Meeting

The October meeting of the Branch was held on the 20th October at the Delmar Supper Club.

After a brief reception and a good dinner, the Branch Chairman, Mr. J. R. S. Hutton, welcomed 51 members and 13 guests who attended the meeting. After conducting a short business session, the Chairman called on Mr. Bingham to introduce the speaker of the evening, Mr. Goodmanson of Boeing Airplane Company.

Mr. Goodmanson's subject was "Supersonic Transport" on which he gave a most interesting talk, which was well illustrated with colored slides. He explained the parameters governing cruise speed, size, range and the economics of future air transportation. The rather animated discussion period which followed was finally called to a halt and Mr. McWilliams thanked the speaker on behalf of those present for a very interesting talk.

Ottawa

Reported by W/C A. N. le Cheminant

October Meeting

The Ottawa Branch started late with an inaugural meeting on the 29th October. The lateness stemmed from two major factors, difficulty of obtaining a speaker at the right time and loss of our normal meeting place at Beaver Barracks through a change of policy on such matters by those responsible for the building. Very fortunately we have been able to make arrangements at the Gloucester Street Mess which enabled our first meeting to be held there as well as the planned November meeting and Ladies' Night. Despite a spate of travel by almost all of the Branch Executive, three meetings were held in the late Summer-early Fall period, largely to plan forthcoming activities.

Returning to the October meeting, the Chairman, CDR N. A. Smith, opened the meeting of some 60 members and guests by introducing the Branch Executive and, where appropriate, giving them the opportunity to outline their respective plans for the season. Mr. D. O'Donnell, Program Committee Chairman, outlined the program for the next two meetings and the tentative ones for the period after the Festive Season. S/L J. Harrison, Membership Committee Chairman, promised to rectify our drop in membership from 318 to 317 before the cessation of the year's activity.

Our guest speaker, Mr. R. S. Lickley of Fairey Aviation Ltd., was introduced by the Chairman and Mr. Lickley launched into a most instructive, illuminating and well illustrated lecture on the "Concept, Design and Development of the Fairey Rotodyne". While apologizing for the sales talk aspects of the presented material, Mr. Lickley's first hand knowledge and tremendous interest in what may yet prove to be one of the most promising passenger carriers yet devised, was most marked. Mr. Lickley paid tribute to the early work in the design stages of Captain Forsyth and Dr. Bennett and the more than seven years of testing and background that is behind the present successful prototype. He stressed some of the simple features of the construction; wing to fuselage, pylon to fuselage and rotor to pylon are just a matter of 4 bolts in each case. Elimination of ground resonance is by dashpots built into the undercarriage system. Ground mockups and extensive test procedures at full scale had contributed much in furthering the project not to mention over one million feet of 35 mm film which had been shot during tests. Excellent slides showed earlier designs which progressively became uglier, test results, construction shots and test setups. A short movie depicting the Rotodyne in action between European capitals pointed up its possibilities. The question period demonstrated that the audience were not allowing the sales talk side to be accepted without question. Mr. Lickley's replies further demonstrated his mastery of the subject and the considerations which had gone into decisions which had been made. The present Rotodyne's handicap of power which should easily be eliminated in future aircraft was an interesting point.

CDR J. Frank, RCN, aptly expressed on behalf of the Branch our thanks. We were also glad to see in the audience Mr. Hibbert of Fairey Aviation of Canada.

November Meeting

An Executive meeting was held on October 26th, 1959, to lay the final plans for the Luncheon Meeting at which Dr. York will speak on December 10th, 1959. Mr. G. Watson, Vice-Chairman, gave a progress report and an outline of the proposed program.

Our Annual Ladies' Night was attended by some 80 people representing members, wives and guests. This is hardly representative of our membership though an intensive telephone campaign was carried out (as planned before the Secretary's error of leaving the date off the notice made it imperative!)

All that can be said is that those who did not attend missed a stupendous buffet supper and those that know the Air Force traditionally high standard in this regard will know of what I speak. Mr. F. Wood of TCA pitched his talk on "Air Transportation and the Jet Age" in a vein that the ladies could enjoy to the full, while there was material enough to provoke thought for the more serious minded.

Starting by reference to a little history and claiming not a little fear of both ladies and technical types, he, in fact, appeared to enjoy both in the course of his talk, which explained TCA's choice of the Viscount, Vanguard and DC-8 for duty over the next few years. Touching on ground equipment, airports and even terminal buildings he paid tribute in many directions to those associated with the present and projected hopes of air transport. Greater efficiencies and an amusing comparison of the capacity of a DC-8 to 3½ Constellations, 19 DC-3s, 32 buses, 236 automobiles brought out the point of need for appealing to a wider public. Weather compensating lighting, cool blue white in summer, orange to reds in winter and background music were among the luxuries planned in aircraft now on order. Ending on a note on the value of air transport in getting people and nations together, Mr. Wood was not let off too lightly during the question period.

G/C E. P. Bridgland thanked the speaker on behalf of the Branch.

Toronto

Reported by C. F. deJersey

October Meeting

The second meeting of the season was held in the De Havilland Aircraft of Canada Cafeteria on Tuesday, October 27th, 1959.

The audience of 66 was welcomed by the Branch Chairman, Dr. J. H. T. Wade, who in turn called upon S/L A. Chivers-Wilson to introduce the guest speaker, W/C I. A. H. MacFarlane, Officer Commanding No. 404 (Maritime Patrol) Squadron, RCAF Station Greenwood, N.S., who had accepted the Branch's invitation to speak on the subject of "Maritime Operations".

W/C MacFarlane opened by reviewing the history of Maritime Operations from World War I, including the early carriers, catapult launching, operations from a towed barge to World War II and the development of the modern maritime aircraft.

The speaker then told of the varied roles combined under Maritime Operations, e.g. reconnaissance, bombing, torpedo dropping, spotting the effects of gunfire, mine laying, anti-submarine warfare and, in peace time, fishing patrols and coast guard duties.

Since the submarine is considered a major threat, not only as a commerce killer but now as a platform for missiles designed to include the destruction of land targets, W/C MacFarlane recalled the history of submarine warfare and then described the weapons known to

Dr. J. H. T. Wade addressing the meeting

Dr. J. H. T. Wade and W/C I. A. H. McFarlane

be in the hands of our adversaries and of the counter measures available for their location and destruction.

The speaker described the various aircraft available for Maritime Operations and discussed the problems confronting the earlier types, which in turn led to the development of the Argus aircraft. The remark that flights of 22 hours were not uncommon underlined the significance of an aircraft having the Argus dimensions, since crew fatigue would obviously be of major importance on such missions.

Crew selection and training were also detailed by W/C MacFarlane, who summed up his most interesting talk with a description of a typical mission of the type undertaken by Maritime Air Command.

A lively question period followed the talk and was concluded by Dr. Wade, who thanked W/C MacFarlane for not only having travelled from Greenwood especially for the meeting but also for proving such an excellent speaker.

Montreal

Reported by W. H. S. Bird

November Meeting

The regular monthly meeting of the Branch was held at the Airlines Restaurant, International Aviation Building, Montreal, on the 18th November. The Branch Chairman, Mr. R. F. O. Smith, presiding. Fifty-six attended the dinner including ten guests, four members of the Students' Section and two visitors from the Winnipeg Branch. Eighty-eight were present for the talk.

Mr. D. Bogdanoff introduced the speaker, Dr. George, who, as an ex-Montrealer, had many old friends in the audience. Dr. George, with the aid of slides and a film described some of the work done by AVCO and other space groups in endeavouring to solve the problem of recovering space vehicles undamaged.

He described re-entry as that period "when everything happens at once" – where forces can range from as low as 10g for an orbiting object and 60 to 80g for an ICBM to as much as 400g for a free space object where the penetration angle is close to vertical. At the same time, temperatures due to air friction can be so high that ionization takes place, effectively shielding telemetering equipment in the nose cone.

Developments of suitable test tunnels from the 1946 shock tube to the present plasma-arc were outlined. Development of nose cones capable of standing the heats involved were also outlined from the early "copper kettle" heat sink type to the present blunt-nosed "cone" which relies on ablation of the nose skin material to absorb and carry away heat. Other problems included insulation of payload, etc., and it was mentioned that studies had been made concerning missiles to planets such as Mars and Venus.

The film showed recovery of the first recovered nose cone as used with Atlas and Titan missiles.

In response to a query as to the stability of the present blunt-nosed cone, Dr. George stated the center of pressure was on the surface of the arc of the cone with the c.g. relatively close behind, that it was in fact quite stable and the biggest problem was oscillation due to dynamic instability at ultrasonic speeds.

Concerning a query on moon landings, the lack of aerodynamic braking would necessitate fitment of retro-rockets.

Recovery of an inflatable vehicle was discussed and although the problem is being evaluated it was thought that the temperature problem was still too severe for even stainless steel.

The speaker was thanked by Mr. R. Raven for a very interesting talk.

APPOINTMENT NOTICES

The facilities of the Journal are offered free of charge to individual members of the Institute seeking new positions and to Sustaining Member companies wishing to give notice of positions vacant. Notices will be published for two consecutive months and will thereafter be discontinued, unless their reinstatement is specifically requested. A Box No., to which enquiries may be addressed (c/o The Secretary), will be assigned to each notice submitted by an individual.

The Institute reserves the right to decline any notice considered unsuitable for this service or temporarily to withhold publication if circumstances so demand.

Positions required

Box 109 **Engineer:** Canadian Citizen with Cambridge University Master's Degree and 20 years continuous experience in aeronautical engineering, seeks a new responsible position preferably in the Toronto area. Experience includes: RAF Engineer Officer, technical sales, technical administration, research, aerodynamics, thermodynamics, electronics, meteorology and instrument design and development. AFRAeS in 1947; AFCAI in 1954.

Box 110 **RCAF Aeronautical Engineering Officer** shortly leaving the service on completion of a short service commission seeks position in the aircraft industry in Canada. Educated in England to Higher National Certificate standard, his background includes six years at the Royal Aircraft Establishment, Farnborough, as a student apprentice followed by a term as Assistant Experimental Officer engaged in research and development on reinforced plastic structures. His present position involves close liaison with industry in the repair and overhaul fields. Member grade in the CAI is held. A full personal history will be sent on request.

Position vacant

Technical Author (Electrical): Required by an aircraft plant in Edmonton, Alberta. Applicants must have had at least three years experience in Aircraft Publications work. Good salary plus relocation expenses to an approved case. Medical and hospitalization benefits plus pension plan, after a qualifying period. Write giving full particulars of age, education, qualifications and salary required to: Industrial Relations Manager, Northwest Industries Limited, Box 517, Municipal Airport, Edmonton, Alta.

MEMBERS

NEWS

S. L. Britton, F.C.A.I., has been appointed Chief Engineer of Orenda Engines Limited; he was formerly Deputy Chief Engineer.

B. A. Avery, A.F.C.A.I., formerly Chief Engineer has been appointed Vice-President and Assistant General Manager, and a Director of Orenda Engines Limited.

J. R. K. Main, A.F.C.A.I., has recently been appointed Regional Superintendent of Airport Property Management for Headquarters Region of the Department of Transport.

Dr. B. G. Newman, A.F.C.A.I., has been appointed Professor of Aerodynamics, McGill University, Montreal. The Chair of Aerodynamics at McGill was made possible by an endowment given by Canadair Limited.

T. P. M. Cooper-Slipper, M.C.A.I., formerly Chief Test Pilot at Orenda Engines Limited has left Canada to join A. V. Roe Limited in the U.K. in a technical sales capacity.

P. W. Painter, M.C.A.I., has recently taken the position of Technical Officer with Canadian Standards Association in Ottawa.

V. V. R. Symonds, M.C.A.I., has recently been appointed General Manager of Spartan Air Services Limited.

D. J. Tynan-Byrd, M.C.A.I. has taken a position in the Research and Advanced Development Dept. of Canadair Limited.

A. Wharton, M.C.A.I., formerly Experimental Officer for the British Ministry of Supply has taken a position with Vickers Armstrong (Aircraft) Limited, England, as a Senior Weights Engineer.

C. A. Bond, Technical Member, has recently taken a position in the Methods Department at Canadian Aviation Electronics.

N. D. Brewer, Technical Member, has taken a position as Computer Applications Specialist with Computing Devices of Canada Limited.

L. F. Bolger, Technical Member, has left the RCAF and taken a position with the Shell Oil Company in Calgary.

E. K. Prentice, Technical Member, formerly with Avro Aircraft Limited has recently taken a position in the Pioneer Saw Division of Outboard Marine in Peterborough.

ADMISSIONS

At a meeting of the Admissions Committee, held on the 26th October, 1959, the following were admitted to the grades shown.

Associate Fellow

W. T. Heaslip (on transfer from Member)

W/C E. E. McCullough (on transfer from Member)

Dr. J. H. T. Wade (on transfer from Member)

Member

L. B. Box (on transfer from Technical Member)

T. Marshall (on transfer from Technical Member)

N. V. McEachern (on transfer from Technical Member)

G. D. M. Wharton, Canadian Representative, Blackburn & General Aircraft Ltd., Brough, E. Yorks, England: *315 Holmwood Ave., Apt. 1108, Ottawa, Ont.*

Technical Member

E. E. Perras, Electronic Technician, Northwest Industries Ltd., Edmonton, Alta.: *9907 - 108th St., Suite 8, Edmonton, Alta.*

L. R. Smith, Liaison Engineering, Avro Aircraft Ltd., Malton, Ont.: *53 St. Louis Ave., Riverside, Ont.*

Mrs. V. M. Wells, Cost Engineer, Aircraft Branch, Dept. of Defence Production, Ottawa, Ont.: *Box 259, Prescott Highway, R.R. No. 2, Ottawa, Ont.*

Student

C. F. Vail, Provincial Institute of Technology and Art, Calgary, Alta.: *806-15th St. N.W., Calgary, Alta.*

Associate

D. L. Zieroth, Service Engineer, Aeroquip (Canada) Ltd., Toronto, Ont.: *Box 812, Rosemere, P.Q.*

R. H. Skeldon (on transfer from Junior Member)

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At a meeting of the Admissions Committee, held on the 19th November, 1959, the following were admitted to the grades shown.

Associate Fellow

R. J. Thomson (on transfer from Member)

Member

W. R. King, Senior Technical Sales Representative (Aviation), S. Smith & Sons (Canada) Ltd., Don Mills, Ont.: *63 Braemore Gardens, Toronto 10, Ont.*

F/L J. A. P. Normand, RCAF, Aircraft Performance Analyst, RCAFHQ, Ottawa, Ont.: *96 David Dr., City View P.O., Ottawa, Ont.*

E. R. Semple, Jr., Systems Engineer, Missiles & Systems Div., Canadair Ltd., Montreal, P.Q.: *2032 Filion St., St. Laurent, Montreal 9, P.Q.*

E. A. Westall (on transfer from Technical Member)

COMING EVENTS

IRE/ASQC/EIA/AIEE

11th to 13th January — *6th National Symposium on Reliability and Quality Control in Electronics,* STATLER-HILTON HOTEL, WASHINGTON, D.C.

(Information: Mr. C. I. Soucy, AMC, RCAF Station, Rockcliffe, Ottawa)

IAS

25th to 28th January — *28th Annual Meeting,* HOTEL ASTOR, NEW YORK

CAI

19th and 20th February—*Mid-season Meeting,* KINGSWAY MOTOR HOTEL, EDMONTON

BRANCHES

Cold Lake

19th January — *Scientific Exploration of Space,* G. D. Watson, DRB, Scientific Advisor to the Chief of General Staff.

Vancouver

20th January — *Bypass and Fan Engines,* Panel from Rolls-Royce, General Electric, Pratt & Whitney and Bristol

Winnipeg

22nd January — 6.30 p.m., WINNIPEG FLYING CLUB, *Scientific Exploration of Space,* G. D. Watson, DRB, Scientific Advisor of the Chief of General Staff.

Vancouver

15th February — *Space Flight,* Boeing Aircraft Co. (Joint with SAE)

SUSTAINING MEMBERS

Garrett Manufacturing Limited have announced that a new line of aircraft galley refrigerators, designed to improve air passenger service and comfort, has been developed.

Use of the new refrigerators in aircraft permit the operator to meet passenger demands for a wider variety of foods and drinks plus provision for storage of perishables.

Previously, use of refrigerators, essentially designed for commercial use in aircraft, has been guided by weight, bulk, quality requirements and performance. Garrett's new range of refrigerators meet and exceed these special requirements.

This refrigerator line features a lightweight, high strength box incorporated, if desired, as an integral part of the galley structure. The box is constructed of reinforced moulded fibreglas, inner and outer shells bonded into a single unitized structure using foamed polyurethane. An extremely light assembly results with very high thermal insulation properties.

As box shape and capacity present no particular problem with this construction method, the unit can be tailored to meet custom requirements. A full range of colours is available to match any aircraft decor, while clean sheer lines give the aircraft refrigerator the modern look of the luxury type household appliance.

Freezing compartments are optional. A recent production unit of 3.25 cubic feet capacity, weighing less than 80 pounds, completed for use in the Canadair CL-44 does not incorporate a freezing compartment.

In this particular application, a fast pull-down time was essential, with food to be maintained at a uniform, unfrozen temperature of 35°F. These particular results were obtained by the use of a high-performance circulating fan.

Other exacting customer demands can be met with equal facility.

Canadair Limited have announced a joint sales research program with the Flying Tiger Line which will bring airfreight rates down to levels competitive with many truck and rail freight rates.

Both companies have agreed on a programme and supporting budget which will involve an expenditure of approximately $200,000 in the next year.

They have joined in this venture for mutually beneficial reasons. Canadair, as builder of the CL-44D, which will be the first turboprop swing-tail airfreighter, is vitally interested in the economics of low-cost airfreight. Flying Tiger has on order a fleet of 10 CL-44D-4's, which it will place in service in 1961. The airline is seeking a tariff for this new airplane which will effect a breakthrough into freight rate areas on an average of 30 to 40% under today's existing rates.

The companies believe that rates as low as 6 cents a ton mile are possible with the CL-44D-4 and that they can achieve an average rate of some 13-14 cents, compared with the existing average of 18-19 cents.

Studies previously made by consultants engaged by the companies clearly indicate that such rate levels should create an airfreight market from seven to ten times today's volume.

The research program has two phases:

(1) To analyze in detail, the characteristics of cargo presently being hauled by the Flying Tiger Line.

(2) To identify, locate, measure and determine the characteristics of commodities which are air potential and can move by air rather than surface in the immediate future.

Work on Phase 1 of the program has now been completed and work on Phase 2 of the program is well under way.

Phase 2 of the program will involve a study of all commodities presently moving by surface in order to identify air potential. Subsequent to the identification of commodities which are air potential, such characteristics as value, volume movement, weight, dimensions, tariffs, density, origin and destination, directional movement and distribution costs will be studied.

It is the opinion of both companies that effective development of the market for air cargo space is dependent, to a great extent, on a thorough knowledge of the commodities which can be economically transported by aircraft. The co-operative research program is aimed at gaining such knowledge.

In a rather different field of research Canadair Limited has endowed a Chair of Aerodynamics in the Department of Mechanical Engineering at McGill University in Montreal, and the appointment of Dr. B. G. Newman as Canadair Professor in that Chair.

The university's research program includes the construction of a small supersonic wind-tunnel which will allow for experimentation at speeds up to 2,800 mph – four times the speed of sound – and two medium-size low speed wind tunnels for research up to 150 mph.

The research program is designed to assist the Canadian aircraft industry.

Spartan Air Services Limited have announced that proposals will be submitted shortly providing for a reorganization of the Company's affairs, which proposals will require prior approval of the various interested parties. Upon satisfactory completion of the reorganization **The Bristol Aeroplane Company of Canada Limited** has indicated it will subscribe for a substantial portion of the Company's common stock.

BOOKS

Electromagnetc Radiation from Cylindrical Structures. By JAMES R. WAIT, Pergamon Press, London, 1959. 200 pages. Illus. $8.00.

This book will be available to scientists and engineers who develop radiation systems for high speed aircraft and missiles. The author presents an excellent summary of the literature on slot antennae as an introduction to his comprehensive theoretical studies of the patterns and other radiation characteristics of slots on various types of cylindrical surfaces.

The extent of the interest in slot antennae during World War II may be judged by the fact that 95% of the references are papers written after 1939. The breadth of the author's background is evident from the fact that 24 of the 122 references were written by him as author or co-author. All of the author's papers were written during the previous seven years.

The author derives the formulae for the radiation pattern functions of slots on circular cylinders, wedges, cylindrically-tipped wedges and elliptic cylinders. The numerical values of the amplitude of the derived functions are plotted for a large number of applications. The numerical values of some of the functions are on file at the Computation Centre at the University of Toronto.

The author's contributions cover a broad field and are characterized by a high degree of originality. In several cases, the author extends the work of authorities such as Lord Rayleigh and E. B. Moullin to cover more general problems. These interesting generalizations include the scattering of a plane wave from a dielectric cylinder at oblique incidence, the development of the harmonic series representation for the pattern of a slotted cylinder antennae, the development of the theory of corner reflector antennae for a corner reflector of any angle, the modification of Stevenson's formula for resonant slots due to the finite extent and curvature of the baffle, the effects of covering the slots with a dielectric coating, and the pattern calculation for arrays of slots using the principle of superposition.

The presentation in the text assumes that the reader is familiar with electromagnetic theory. A thirty page appendix includes an excellent review of the basic concepts of electromagnetic field theory and of the theory of radiation from slots.

W. E. WHITE

Aircraft Engines of the World—1959-60. By P. H. WILKINSON. Washington, D.C., 1959. 320 pages. Illus. $15.00.

Over the past seventeen years, Mr. Paul H. Wilkinson's volumes, although mainly devoted to specification data, have, in simplified form, portrayed a picture of aircraft engine development. In this edition the appearance of a number of new models, developed from proven configurations, and the advent of several small reciprocating, turbojet, turboshaft and turbo-compressor engines, heralds the progress over the past year.

With the current interest in missiles and space vehicles mounting steadily it seems necessary to emphasize, with no discredit to the author, this book was written to cover, exclusively, the engines of manned aircraft.

On reviewing this book it appears progress in large engines is approaching a negative trend since the number of program casualties, occurring recently, threatens to exceed the introduction of new developments. Further cancellations, in this exclusive category, could delay appearance of a supersonic transport and seriously jeopardize the possibility of a supersonic travel for this generation of airline passengers.

The article, summarizing progress in nuclear propulsion, leaves no cause for complacency for those of the free world interested in competing with developments emanating from other parts of this earth.

The latest commercial jet engine specifications, as outlined, mark the acceptance, finally, of the turbofan or by-pass principle, so long promoted by certain groups, as the optimum engine for the subsonic transport and bomber.

An increase in useful tabulations is evident including data relative to fuels and lubricants, a listing of helicopters and their powerplants, a comparison of all gas turbine commercial aircraft, an international listing of military aircraft with their engines and an index of earlier engines not otherwise covered in this text. Also detailed are some interesting advancements in engine accessories, equipment and materials.

In summary this book continues to progress in step with the engine industry; adding each year useful material of everyday value to those in the aviation industry.

W. R. COLE

The Physical Metallurgy of Magnesium and its Alloys. By G. V. RAYNOR. Pergamon Press Inc., New York, 1959. 531 pages. Illus. $12.50.

The title of this volume is somewhat misleading since the subjects covered are really in the realm of physics and physical chemistry. The information it contains has comparatively little to do with the physical metallurgy of magnesium and its alloys, from a technological consideration. Although the author, in his preface, indirectly acknowledges this fact, he apparently failed to do anything about it. If he had, perhaps a large number of potential readers would have become disinterested.

As a treatise on this particular subject, the text abounds in mathematical formulae and related data, which undoubtedly would be useful to those concerned with the loftier aspects of the properties of magnesium. Some of the subjects covered are the electronic structure of magnesium, lattice spacings, general alloying behaviour, intermediate phases in alloys, deformation characteristics and alloying properties – all dealt with in a very academic manner.

However, the author should be given a great deal of credit for accumulating all this information, fundamentally highly theoretical, from the extensive literature which has been published on magnesium. To find elsewhere many items of the information included in this book, would require a large amount of effort. A significant number of references which the author has used are those of his own published papers – presumably the results of research work he has personally been concerned with in the field of magnesium.

Those engaged in the higher levels of research will undoubtedly find this book to be very useful and perhaps interesting but to the aircraft or missiles metallurgist, it would be hardly more than a reference book, very rarely used.

J. J. WALLER

Axial Flow Compressors. By J. H. HORLOCK, Butterworth & Co. (Canada) Ltd., Toronto, 1958. 189 pages. Illus. $8.00.

Axial flow compressors are now used almost exclusively to satisfy the compressor requirements of contemporary aircraft gas turbines and they are gaining an ever widening acceptance for industrial applications. They have been

under continuous development in England for over twenty years and in the United States for at least fifteen years. When one considers this general acceptance, it is rather surprising to find that no text books have been written dealing solely with this complex and intriguing device.

This lack has now been remedied, in part, by the appearance of "Axial Flow Compressors" by J. H. Horlock. It is the author's stated purpose to deal with the fundamental fluid mechanics and thermodynamics of axial compressor design. It is not intended to be a complete manual for the designer of an axial compressor, since no one book can hope to deal with all the applied research and development associated with axial compressors that has been carried out by industrial firms and government establishments.

It is a relatively small book containing 189 pages divided into nine chapters. The chapters deal with:

(1) Basic fluid mechanics and thermodynamics.
(2) Theoretical aspects of two-dimensional cascades.
(3) Experimental work on two-dimensional cascades.
(4) Two-dimensional design of compressor stages.
(5) Three-dimensional flow in compressor stages.
(6) Calculation of stage and compressor characteristics.
(7) Stall and surge.
(8) Compressor testing and instrumentation.
(9) Supersonic compressors.

There is an impressive list (187) of references at the back of the book containing most of the useful unclassified material available. Security has forced the author to omit from the reference list, and from useful mention in the book, the very important and extensive work done by the NACA on transonic compressor stages. This information is extremely valuable to anyone designing advanced axial compressors and it is hoped that it can be included in a revised edition of the book when the material is declassified.

The author treats the various subjects concisely and effectively. He redefines his symbols regularly and has very thoughfully placed a list, at the end of each chapter, of all the symbols used therein. The drawings are carefully done and well reproduced and all curves contain a clear scale which permits data to be read from them.

Since the author is British, one would expect him to use the axial compressor symbols originated by Howell, Carter and the other pioneers in this field and now fairly standard in most British publications. This is generally the case but he makes several changes which may disturb people already familiar with normal British terminology. Among these are the symbols for velocity and for air and blade angles which do not follow either British or United States practice.

However this does not affect the general usefulness of the book. The author has assembled his material from both British and United States sources and the book benefits very considerably from this in that the best of two different approaches is obtained. Chapter 5 contains the first text book treatment of the "actuactor disc" approach to axial compressor design. This is a British development in which the author played a major role and it is an important contribution to axial compressor theory. Chapter 7, particularly the section on rotating stall, and chapter 9 on supersonic compressors are enriched by work that has been done in the United States.

This book is an important addition to gas turbine literature. It will be very useful to anyont interested in axial flow compressors but particularly to the engineer who is engaged in their aerodynamic design or development.

K. S. Thue

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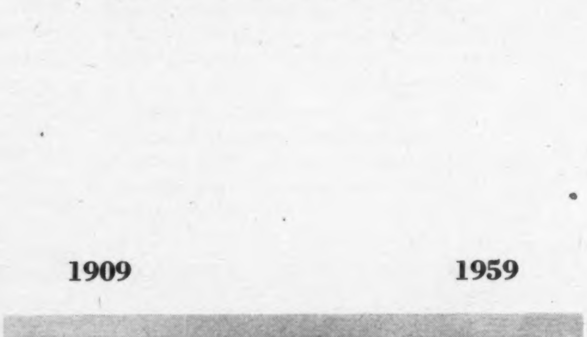

Silver Dart Mk 2 in flight

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